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The exotic new physics found hiding inside ultra-thin materials

New Scientist
QUANTUM FLATLANDS
The exotic new physics found hiding inside ultra-thin materials

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Podcast

Weekly

This week, the team learns about the odd new names, including quecto and quetta, that have just been added to the International System of Units to define mind-bogglingly large – and small – numbers. There is also news of a *New Scientist* investigation into the Colorado river's future and a discussion of the issues left to address after the COP27 climate summit. Plus, Ugandan wildlife vet Gladys Kalema-Zikusoka explains how to move an elephant.

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EAT JUST INC

Food for thought Can lab-grown chicken succeed commercially?

SHUTTERSTOCK/STEPANPOPOV

Made to measure The new words for defining numbers

Video

Quantum consciousness

On our YouTube channel this week, there is footage of our interview with Roger Penrose, the University of Oxford mathematician who shared the 2020 Nobel prize in physics for his research into the mathematics of black holes. He discusses the big bang, his theories on quantum consciousness – and his underwhelmed reaction to the first image of a black hole.

youtube.com/newscientist

Newsletter

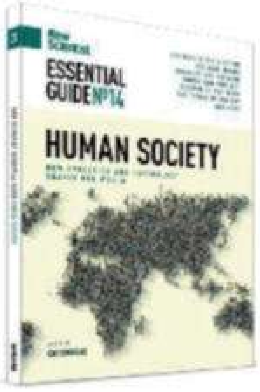
Fix the Planet

While reporting from the COP27 climate summit in Egypt, environment reporter Madeleine Cuff tasted "cultivated chicken" – a form of lab-grown meat. Although the "chicken" was similar to standard meat, she says there are huge hurdles to clear if such products are to succeed commercially.

newscientist.com/ fix-the-planet

Podcast

> "A shipping container is the only thing strong enough to handle an elephant that's awake"



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Space for everyone

We should celebrate the diversity of the next generation of cosmic pioneers

SLOWLY but surely, space is opening up to people and groups who couldn't access it before. As *New Scientist* went to press, Japanese firm ispace was set to launch a lunar lander called Hakuto-R, which – if all goes well – could be the first commercial craft to land on the moon (see page 12). It will carry with it two small rovers, one from the United Arab Emirates and another from the government-run Japan Aerospace Exploration Agency, smashing the US, Soviet Union and Chinese hegemony of previous lunar landings.

At the same time, the European Space Agency has announced its newest class of astronauts, including the first ever astronaut with a physical disability, Paralympian John McFall (see page 16).

These developments are part of ongoing efforts to diversify space. Historically, only a few major powers have been able to operate in space, and around 90 per cent of the astronauts they have chosen have been non-disabled men. Even the growth of private space flight has, so far, sent mostly wealthy white men beyond Earth.

> "Allowing space to remain the domain of a homogenous group harms us all"

Allowing space to remain the domain of a homogenous group of governments and billionaires harms us all. Smaller nations and companies going to space will spread the scientific wealth, allowing researchers from those places to make their own breakthroughs and raising the prospects for those young people trying to enter the space industry to carry out research. Astronauts with physical disabilities will force engineers to innovate in their designs, making space flight possible for everyone.

Down the road, a diverse slate of players in space will serve any permanent settlement well. It will make it difficult to create anything resembling a factory town or indentured servitude, as some would-be space barons have suggested, because there will be multiple employers. And it will bring a broader range of ideas to the table.

Space becoming more diverse is a good thing for everyone, and a signal that the industry is truly ready to take off. ▮

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The future of epilepsy

Our understanding of epilepsy is changing, raising the possibility of a new generation of therapies

The earliest descriptions are on ancient clay tablets from Mesopotamia. "His neck turning left, hands and feet are tense, and his eyes wide open, and from his mouth froth is flowing without him having any consciousness." This man was almost certainly suffering what modern doctors would call an epileptic seizure.

Today, almost 3000 years later, epilepsy is still a devastating disease for the 65 million people living with the condition globally. For many, modern medication and lifestyle changes can control the seizures. But a third of sufferers have a drug-resistant form of epilepsy. For them, the condition is much more serious and the outlook less certain.

However, the science behind treating epilepsy is moving in exciting directions. A growing understanding of the fine-grained details of how and why seizures happen is opening up new areas of research. "In the last three or four years, we have been at a tipping point that has triggered a different way of thinking about epilepsy," says Stefanie Dedeurwaerdere, head of epilepsy research at UCB, a global biopharmaceutical company.

> "This different way of thinking is the key to disease modification"

"It's very early, but we hope there is more we can do for people living with, and impacted by, the spectrum of epilepsy disorders. Something completely innovative," she says.

There are many different types of epilepsy, but the main characteristic is recurrent seizure. Seizures manifest in various ways, many of which are more subtle than the stereotypical description described in Mesopotamian clay. Seizure types vary from a very brief lapse in attention or muscle jerk to severe and prolonged convulsions. Seizures can also vary in frequency, from less than one a year to several per day. In addition, doctors have identified over one hundred different epilepsy syndromes which are characterised by specific signs and symptoms.

Each seizure occurs when neurons in the brain begin to fire abnormally, producing bursts of electrical signals.

Anti-seizure medication has proven to be effective in preventing these electrical bursts in many sufferers by damping down the excitability of neurons.

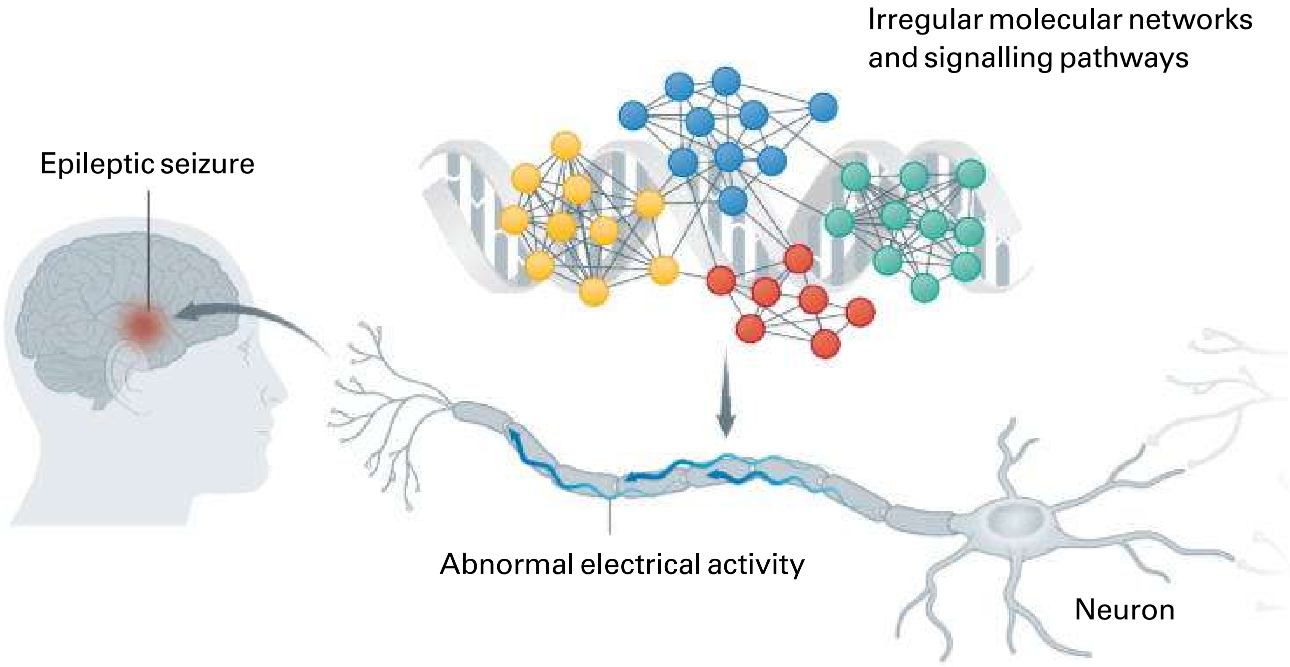
However, anti-seizure medication treats the symptoms of epilepsy, not the underlying cause. "If we are going to change this, we need to do something dramatically different: we need to move further upstream to treat the root cause," Dedeurwaerdere says.

This focus is now becoming possible thanks to "omics" technologies. These are molecular sensing techniques capable of revealing the molecular-level changes of genes, proteins, metabolites and other molecules that cause neurons to over-fire in parts of the brain.

These changes turn out to be hugely complex, involving labyrinthine networks of interactions. As researchers are piecing together how this happens, it is opening the door on a new way to approach treatment. "We can think about it as a whole cascade of pathways that eventually lead to seizures," Dedeurwaerdere says. "This different way of thinking is the key to disease modification: it means not just looking at seizure suppression

CECILIE_ARCURS/ISTOCK

Epileptic seizures have long been linked to regions of the brain with abnormal electrical activity. But a deeper understanding of epilepsy suggests these electrical anomalies are caused by irregularities in networks and pathways that operate at the molecular level.


Irregular molecular networks and signalling pathways
Epileptic seizure
Abnormal electrical activity
Neuron

but modifying the pathways that bring them on. In this way, you could impact more than just seizures."

Researchers had initially thought, for instance, that epilepsy's electrical network abnormality stemmed from ion channel defects leading to "hyperexcitable" neurons. However, large-scale genetic investigations pointed to many different molecular pathways that take part — those involved in signalling, energy metabolism, protein synthesis, axon guidance and so on.

"All of the pathways involved lead to the fundamental problem in epilepsy, which is hyperexcitability," says Annapurna Poduri, Associate Professor of Neurology at Harvard Medical School and the director of the Epilepsy Genetics Program at Boston Children's Hospital.

This new understanding will help guide treatment — although, Poduri warns, success will depend on the specific molecular cause for each group of patients. "I am not sure if we can modify disease in all cases, but I am hopeful that we can improve the course for each patient, perhaps limiting or preventing some symptoms by addressing a precise molecular cause and hopefully making an impact on seizures and cognitive function in as many patients as possible," she says.

HOW TECHNOLOGY CAN HELP

"Digital therapeutics" is increasingly used on a day-to-day basis to help those with epilepsy. Even simple things can reduce the stress of having the condition, such as smartphone apps that help people track their sleep, medication use and stress levels. In some cases, this approach has led to less frequent seizures.

Wearable devices with built in accelerometers can detect certain kinds of seizure and call for medical assistance. As these devices measure and record the severity of seizures, they also help doctors to determine appropriate treatments and preventative measures.

The data from these and other approaches, and the tools to analyse it, is helping too, according to Mike Cousin, at the Muir Maxwell Epilepsy Centre in the University of Edinburgh.

"The use of wider clinical data — big data — has been revolutionised via the use of machine learning to extract key information and reveal underlying patterns of disease progression that would be impossible just looking at small cohorts of patients," he says.

One route forward is "regenerative medicine", which uses stem cells that can be induced to form any of the various kinds of cells in the body — muscle, neurons, skin, blood and so on. Stem cells can be turned into "inhibitory" neurons, or interneurons, which secrete chemicals called GABA inhibitory neurotransmitters that "turn off" other neurons, halting their abnormal electrical activity.

In pre-clinical trials, stem cells have been induced to form interneurons that, once transplanted, significantly reduced seizures in epilepsy models. This work raises the possibility of similar treatments in humans.

Some rare forms of epilepsy are caused by defects in a single gene. This makes them potentially treatable by replacing or repairing that gene. In this way, gene therapy could have the potential to improve outcomes.

Although such techniques are potentially important, they are still in the early stages of development. "The concept is great but the implementation will require a lot of thought and perseverance," Dedeurwaerdere says. Mike Cousin, Chair of Epilepsy Research UK's Scientific Advisory Committee, and a professor at the Muir Maxwell Epilepsy Centre in the University of Edinburgh, agrees. "At present there are still many unanswered questions to be addressed before this becomes widely employed," he says. But, he adds, there is "a significant possibility" that it might provide hope for those for whom the current range of treatments don't offer any improvement. "It will be exciting to see developments over the next few years." Perhaps one day, accounts of seizures will truly become things of the past.

More at: www.ucbpharma.co.uk

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US GEOLOGICAL SURVEY

Lava snaking along the north-east rift zone of Mauna Loa

Geology

Mauna Loa erupts

After a cluster of local earthquakes, the planet's biggest active volcano is erupting in Hawaii, report **Madeleine Cuff** and **James Dinneen**

THE largest active volcano in the world, Mauna Loa in Hawaii, is erupting for the first time in almost 40 years, with US officials warning nearby residents to prepare for possible evacuation.

The eruption, the volcano's first since 1984, began at 11.30pm local time on 27 November at Mokuʻāweoweo, the summit's caldera located inside Hawaiʻi Volcanoes National Park on the island of Hawaii.

At first, the eruption was confined to the summit area, but officials warned that the situation could change rapidly.

Along the sides of the volcano are two so-called rift zones, extending north-east and south-west from the caldera, where the surface of the volcano can crack and split. "Very fluid and fast-moving lava" can quickly run from a new fissure, threatening populated neighbourhoods downstream, said Ken Hon at the Hawaiian Volcano Observatory in a briefing on 28 November.

"Right now, we just don't know what's going to happen – if this is going to stay as a summit-only eruption or move into one of the rift zones," he said.

On 28 November, officials from the US Geological Survey said lava had started to spill out of the summit's caldera, but they said there wasn't yet evidence of lava erupting from the rift zones.

However, as *New Scientist* went to press, the eruption had moved to the north-east rift zone.

A warning for ashfall has been issued for the island of Hawaii, with medically vulnerable residents advised to stay inside or wear filter masks. Shelters have been opened to provide safety for islanders, although there is no immediate threat to populated areas, according to officials.

"Very fluid and fast-moving lava can quickly run from a new fissure, threatening populated areas"

Mauna Loa is a giant shield volcano, stretching to a height of around 4 kilometres and covering a land area of about 5000 square kilometres.

It has erupted 33 times since 1843, most seriously in 1950 when it inundated the coastal town of Hoʻōpūloa within 3 hours, destroying houses, a church and the local highway.

During its last eruption in 1984, lava flows came within about 8 kilometres of the city of Hilo.

Volcanologists have been reporting an increase in activity at Mauna Loa for weeks, with dozens of small, shallow earthquakes recorded around the summit in the past month. "Then it really kicked up right before the eruption started," says Paul Segall at Stanford University in California.

Deeper earthquakes around the volcano over the past few years have indicated that Mauna Loa might be ready to erupt. "This has been on our radar for a while," says Segall.

In a statement, the Hawaiian Volcano Observatory said it will conduct aerial reconnaissance "as soon as possible" to better understand the risks posed by the current eruption.

Segall says the eruption may help volcanologists learn more about the connection between Mauna Loa and another Hawaiian volcano called Kīlauea. "We don't really understand the plumbing system where the magma separates" to flow to the two volcanoes, he says. One possible explanation behind the long delay since Mauna Loa's last eruption is that magma was being diverted to Kīlauea, which saw a major eruption in 2018 that caused a caldera collapse, and has been erupting since 2021.

Segall says he sees no indication at this point that the Mauna Loa eruption could become as forceful as that 2018 eruption. "Statistically speaking, this thing is going to be relatively modest," he says. ▮

Genetics

How Y chromosome could be lost

A species of rat from Japan no longer has the male sex chromosome, and some researchers think it offers a glimpse of our own genetic future, says **Michael Le Page**

FOR any mammal, the loss of the Y chromosome should also mean the loss of males and the demise of the species. So how the Amami spiny rat manages without this chromosome has puzzled biologists for decades. Now, Asato Kuroiwa at Hokkaido University in Japan and her colleagues have shown that one of the rat's other chromosomes has effectively evolved into a new male sex chromosome.

The Y chromosomes in many mammals, including us, have been shrinking over tens of millions of years and could eventually disappear, says Kuroiwa. The spiny rat shows how this might happen, she says.

There are many different sex-determining systems across the animal kingdom, but in virtually all mammals, sex depends on the X and Y chromosomes. If an embryo inherits two X chromosomes, it develops into a female. If it inherits an X and a Y, it becomes male.

This happens because the Y chromosome contains a gene called *SRY* that switches on "male" genes on other chromosomes – most importantly the *SOX9* gene that triggers the development of testes.

The Amami spiny rat (*Tokudaia osimensis*), found on the Japanese island of Amami Ōshima, is one of just a handful of mammals that lack Y chromosomes. What's more, females as well as males have just a single X chromosome.

As the existence of female mammals shows, the shrunken Y doesn't contain any crucial genes, so cells and individuals can survive its loss. In fact, recent studies show it is often lost from cells as men age. But the loss of the Y chromosome from an entire population should result in extinction, because there would be no more males.

To find out how male spiny rats still exist, Kuroiwa and her team first sequenced the genomes of several males and females, but didn't find any variants unique to males. They then looked more closely and found that in male rats, one of the two copies of chromosome 3 has a duplicated region, right next to *SOX9*.

"The Y chromosomes in many mammals, including us, have been shrinking over millions of years"

The team did a number of experiments – including adding the duplicated region to mice – to show that this duplication boosts the activity of *SOX9* and thus effectively replaces *SRY*. This means that the chromosome 3 with the duplication has become a "proto-Y", while the version without the duplication is a "proto-X" (*PNAS*, doi.org/jnx4).

To demonstrate this beyond doubt, the team would have to delete the duplication in Amami spiny rats to show that no males develop, says Robin Lovell-Badge at the Francis Crick Institute in London, one of the researchers who discovered the *SRY* gene. Such an experiment can't be carried out as the spiny rat is an endangered species. "However, the evidence they have is all quite convincing," he says.

The duplication must have arisen sometime after 2 million years ago, as this is when the spiny rats diverged from related species that still have a Y chromosome. Once the duplication was present, the loss of the Y chromosome would no longer result in the loss of all males. Kuroiwa thinks that, for a while, a mixed population of males with and without a Y was probably present on the island.

Then, most individuals died off, probably as a result of rising seas, leaving only males with no Y. "At some point in the past, the sea level rose and the land area was much smaller," says Kuroiwa.

Goodbye to the Y

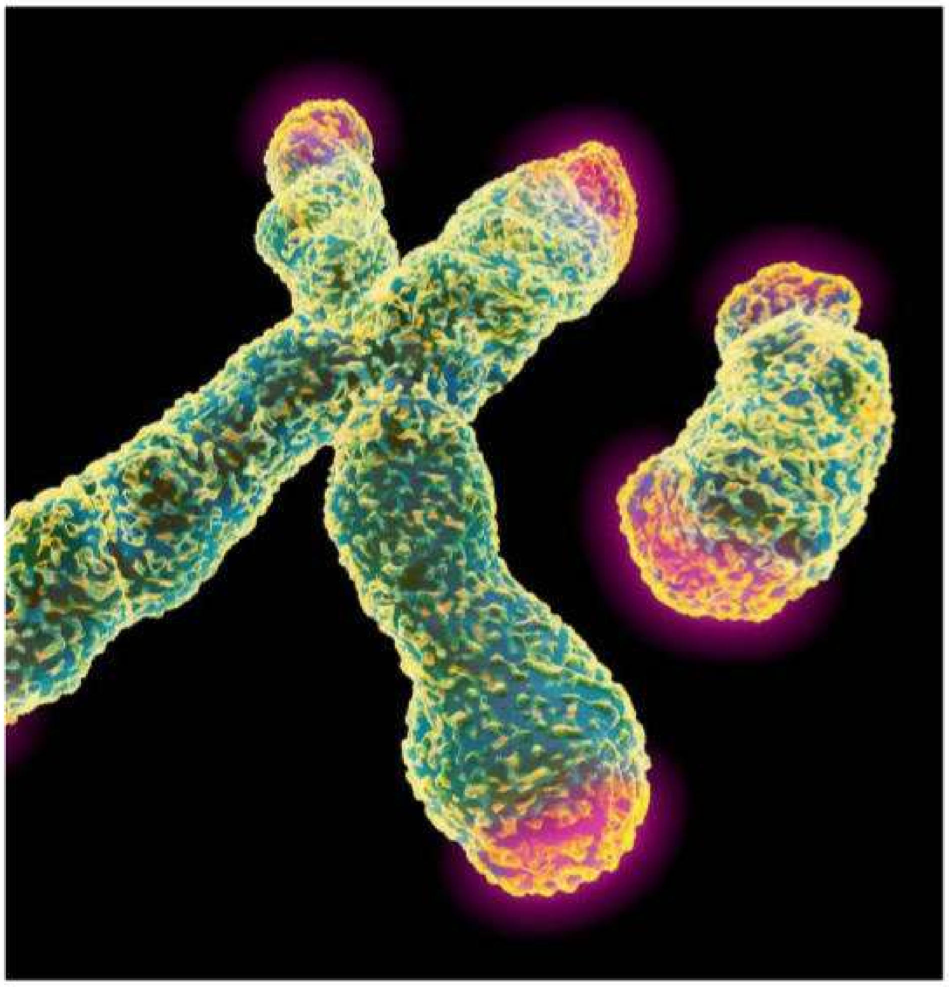
"I think this is a brilliant piece of work. The evidence is very compelling," says Jenny Graves at La Trobe University in Melbourne, Australia, who controversially claimed in 2002 that the human Y chromosome will eventually be lost in around 10 million years. "There's no reason to think our Y chromosome is any more robust than the spiny rat's," she says.

"I absolutely agree with Jenny," says Kuroiwa. "I also believe that the Y chromosome will disappear."

But Lovell-Badge points to a number of studies suggesting that the Y chromosome is doing fine and is in no danger of being lost by us or other mammals. "I think the paper makes it pretty clear that the loss of a Y chromosome in mammalian evolution is a very rare event," he says.

Because both sexes in the Amami spiny rat now have only a single X chromosome, this could also be lost over time. "Since it is unstable and mutations are accumulating, I think that X will eventually disappear," says Kuroiwa.

However, if the descendants of the Amami spiny rat survive long enough, its proto-X and proto-Y chromosomes are likely to evolve along the same lines as the X and Y, with the proto-Y shrinking and becoming distinct from the proto-X.



ALFRED PASIEKA/SCIENCE PHOTO LIBRARY

Artist's impression of an X chromosome and the much smaller Y one

Analysis **Ukraine invasion**

Uncertain future for Ukraine's nuclear power plants

Russia's attacks on the electrical grid are just one challenge facing Ukrainian nuclear power, says **Matthew Sparkes**

STRINGER/ANADOLU AGENCY VIA GETTY IMAGES

Zaporizhzhia Nuclear Power Plant is Europe's largest

UKRAINE'S nuclear power stations have been caught, both politically and literally, in the crossfire ever since the start of Russia's invasion. But last week, for the first time in history, all 15 of its nuclear reactors were taken offline by fighting.

Zaporizhzhia Nuclear Power Plant (ZNPP), near the Ukrainian city of Enerhodar, is Europe's largest nuclear power station and has been in Russian hands since March. Its last working reactor was shut down in September as a precautionary measure. Nuclear plants supply power to the grid when operating, but when shut down they draw power from it in order to run vital safety systems, which means disruption to electricity supply is a major concern.

On 23 November, attacks on power infrastructure in Ukraine by Russian forces led to blackouts that caused emergency diesel generators to start up at ZNPP, as well as at reactors across Ukraine's three other nuclear plants.

In a statement on its website, Ukrainian nuclear operator Energoatom said that for the first time in the 40-year history of the Ukrainian nuclear power industry, all of its nuclear power plants weren't producing power, instead relying on generators. Access to the national grid resumed on 25 November.

Recent rumours on social media suggest that ZNPP could be returned to Ukraine as part of concessions designed to prevent a major counteroffensive against Russian forces. They were lent some credence by the International Atomic Energy Agency claiming it was holding high-level consultations with Russia about implementing a "nuclear safety [and] security protection zone" around ZNPP. The IAEA didn't respond to a request for comment.

> "For the first time in Ukraine's history, all 15 of its nuclear reactors were taken offline by fighting"

Jacopo Buongiorno at the Massachusetts Institute of Technology says he is sceptical about the idea that Russia is going to return anything of value to Ukraine, but that if it did, long preparations would be needed before the plant could be restored to working condition.

"Restarting the plant would be a lengthy job. Think months, not weeks," he says. "There are equipment and structures to repair, spare parts to acquire, staff to bring back and new staff to hire and train. A couple of reactors might be in good enough conditions to restart sooner, but for full capacity, it's likely months."

He says that four of ZNPP's reactors are on "cold shutdown" and completely dormant, while two are being retained on "hot shutdown", a kind of standby mode. Returning just those two to working order would take months, even if the war ended tomorrow and Energoatom resumed control. Buongiorno says that the plant is operating on "shoestring" staffing levels, and that vital spare parts won't have been delivered at the optimum rate.

Olena Pareniuk, a scientist working at the Chernobyl site, says the process of restarting a nuclear power plant is long and difficult, but that the energy supply is sorely needed by Ukraine's citizens, who are experiencing widespread blackouts across the country.

"It won't [come in time to] help us through winter," she says. Equipment will need to be checked, which is a job that cannot be rushed, she says. "Energoatom says it will be fast, but nuclear-grade 'fast'." ▮

Zoology

Death metal singing technique is also used by chatty bats

Sam Jones

BATS are known for their high-frequency calls, which they use to echolocate and catch prey, but they also let out much lower-frequency social calls between bats – and it turns out the vocal structure behind these sounds is the same one used by growling death metal singers.

Jonas Håkansson at the University of Colorado Colorado Springs and his colleagues affixed microphones to larynges dissected from Daubenton's bats (*Myotis daubentonii*) and placed them under a microscope. They then filmed the larynges as they funnelled air up through each, causing the structures inside to vibrate and produce sound. The team pinpointed two laryngeal structures responsible for the extreme highs and lows of a bat's vocal range, which spans three or four more octaves than the average human's (*PLoS Biology*, DOI: 10.1371/journal.pbio.3001881).

They found that high-frequency echolocation calls are produced by thin, translucent vocal membranes that rest atop the vocal cords. Lower-frequency squeaks came from their false vocal folds, which get their name from the fact that humans don't use them for speech.

False vocal folds are, however, believed to be used by extreme vocalisers like death metal grunters. In a way, says Coen Elemans at the University of Southern Denmark, social squeaks are a bat's version of death metal. "It's a very high-frequency sound for us," he says. "But for them, it's extremely low."

Although the average human can't compete with a bat, Elemans says the exceptional vocalist shouldn't lose hope. For example, Mariah Carey has a five-octave vocal range and is known for being able to sing extremely high tones called whistle notes. "If Mariah Carey would be very good at grunting, she could also extend her vocal range even further." ▮

Health

Boarding school rules help teenagers to get more sleep

Alice Klein

ADOLESCENTS could get almost 5 extra hours of sleep per week if they have a consistent lights-out time and no phone access in bed, according to a study that analysed boarding school students who followed these rules.

"It's a naturalistic experiment showing that the secret to good sleep in teenagers is quite simple: a regular routine and no mobile devices at night," says Kurt Lushington at the University of South Australia.

Lushington and his colleague Alex Reardon studied the sleep patterns of 59 boarding students and 250 day students at a high school in Adelaide. The students were 15 to 18 years old and a mix of boys and girls.

The boarders had to leave their phones in a kitchen area or on their desk before they went to bed and turn out their lights by a set time, which varied according to their age.

The boarders slept for 40 minutes longer per night than the day students, averaging 8 hours and 26 minutes, compared with 7 hours and 46 minutes.

"I think this shows that if you put these norms in place, kids will go along with them," says Lushington, who presented the results at the Australasian Sleep Association meeting in Brisbane in November.

Asaduzzaman Khan at the University of Queensland in Australia doesn't recommend that parents take a teen's phone away, but rather have a discussion to reach an agreement on a phone curfew.

This is more likely to work if parents do likewise and offer other entertainment, like books, says Khan. "It can be a real challenge and there's no one-size-fits-all approach, but I think it's worth trying for the benefits to mental and physical health, attention, learning ability and academic performance that come with extra sleep." ▮

Space exploration

Japanese firm races to make first private lunar landing

Leah Crane

ISPACE

Artist's impression of the Hakuto-R lander on the moon

A JAPANESE company called ispace is getting ready to go to the moon. If the Hakuto-R lunar lander is a success, it will be the first spacecraft funded and built by a private firm to land on the moon – provided it isn't beaten by competitors set to launch next year on a more direct route through space.

The Israeli non-profit SpaceIL made a similar landing attempt in 2019 with the Beresheet spacecraft, but it experienced a fatal engine flaw during the landing phase and ended up crashing into the lunar surface. Like SpaceIL, ispace started working on its lander as part of the Google Lunar X Prize, which offered a cash prize to the first successful moon landing not funded by a government. The prize ended without a winner in January 2018, and so far, only governments – the US, the Soviet Union and China – have managed to land on the moon.

Since the X Prize, ispace has signed contracts with NASA and the European Space Agency for future missions to land on the far side of the moon and collect samples of lunar dust and water, as well as other collaborations with companies and agencies around the world.

Its first mission, called M-1, was due to launch on a SpaceX Falcon 9 rocket from Cape Canaveral in Florida as *New Scientist* went to press. The lander carries a small rover for the United Arab Emirates's Mohammed bin Rashid Space Centre, an even smaller two-wheeled robot for the Japan Aerospace Exploration Agency and a camera and flight computer prototype for Canadian companies. If it succeeds, it will also be the first time a craft from Japan or the United Arab Emirates has visited the lunar surface.

2

Height of the Hakuto-R lunar lander, in metres

Hakuto-R's path to the moon is a circuitous one, designed to require less fuel so the spacecraft can fit more scientific payloads aboard. Rather than flying straight there, it will use the gravity of Earth and the sun to give it an extra push during its four-month voyage. The 2-metre-tall craft will weigh about 1000 kilograms when it launches, but most of that mass is propellant that will be burned on the way, and the lander will have a mass of only 340 kilograms by the time it touches down.

Once it arrives at the moon, it will spend about two weeks in orbit, with each circle around the moon taking it closer to the surface. Finally, if all goes well, it will land softly in an area called Atlas crater.

There is a potential wrench in ispace's plan to be the first private firm on the moon, though: there are two other contenders, both from the US. While both the Nova-C lander, built by Intuitive Machines, and the Peregrine lander from Astrobotic aren't scheduled to launch until early next year, they will take more direct routes to the moon and could beat Hakuto-R there.

"We don't care very much about who is going to land first," says ispace founder and CEO Takeshi Hakamada. "Our vision is to create an economically viable lunar ecosystem – I don't think it's possible to do that with only one company, so we want several companies to do business there." The company has two more lunar missions already in development, with the goal of maintaining momentum with launches in 2024 and 2025. ▮

Artificial intelligence

BBC film used face-swapping AI to hide the identities of Hong Kong protesters

Matthew Sparkes

AN ARTIFICIAL intelligence helped to protect the identity of people who took part in an anti-government protest in Hong Kong by swapping their faces for those of actors. The method was used in a new BBC documentary, with filmmakers saying it safeguards protesters, who were interviewed on camera, from persecution while also conserving their mannerisms and the emotions conveyed in their expressions.

The BBC2 documentary, *Hong Kong's Fight for Freedom*, features interviews with four protesters who took part in demonstrations following the proposal of a law that would allow criminal suspects to be extradited to China.

Possible government reprisals meant that the identity of the interviewees had to be protected. Rather than covering them with a black bar, filming them in silhouette or pixelating images, the BBC used AI to change the faces of these people while retaining their original movement.

Ryan Laney at US-based TeusMedia, who developed the AI, says the effect was deliberately not entirely convincing. This means a viewer may be aware that changes had been made to the speaker's face, but the effect was accurate enough to convey when they smiled, for example, he says.

BBC

Each interviewee had their face switched with that of an actor

"The shape of skulls, ear folds and facial structure were also changed to avoid giving biometric clues"

The AI process involved an actor being filmed for around 5 minutes in lighting conditions similar to those used for the interviews with the protesters. The actor read a generic statement that covered the facial movements that are created when all the various vowel and consonant sounds are made.

This video was then fed into an AI model, along with footage of the interviewee. The resulting model was specific to that actor-interviewee pair and could work on new footage of the interviewee.

Laney says the shape of the interviewee's skull, ear folds and skeletal structure of the face were all changed to avoid Hong Kong authorities trying to identify them from biometric clues.

Toby Paton, who directed the documentary, says the concept of AI disguises was "tricky" to explain to cautious interviewees, but that framing it as a type of "deepfake" was quickly understood. The BBC asked for the term "deepfake" not to be used in the documentary because of its negative connotations. For example, deepfake technology can create videos of politicians seemingly saying something they have never actually said.

Paton says that protecting those in the film had to be considered alongside conveying interviewee emotions that could be lost by using cruder obscuration.

Jane Singer at City, University of London, says this kind of AI is a powerful technology with the potential to be abused. "It's OK, but only if it is explicitly made super clear to viewers what has been done," she says.

The documentary begins with the disclaimer: "The protesters in this film could be imprisoned for what they tell us. We have protected their identities using artificial intelligence." ▮

Technology

Drones on strings puppeteer people in virtual reality

A DRONE attached to you by strings could provide a more realistic simulation of the forces you should feel when interacting with things in virtual reality.

Various tricks have been used to make VR more immersive and convincing, including fans to mimic wind and muscle vibrations that fool nerves into perceiving weight.

Now, Martin Feick at Saarland University in Germany and his colleagues have created a system that uses a drone attached to a finger by a string to mimic the feel of pressing a physical button. It simulates the button's resistance by pulling on the string. Next, the researchers hope to run tests using multiple drones attached to different parts of the body.

The drone they tested is just 95 millimetres across and weighs 72 grams. Its onboard battery allows a flight time of up to 7 minutes (*UIST '22 Adjunct*, doi.org/jnt2). Feick says there are challenges with keeping a drone stable while it pulls on the string.

MARTIN FEICK

A drone that moves your finger to give the sensation of touch

The tiny machines can begin to oscillate or drift, and coordinating multiple drones so they don't crash or tangle strings will be difficult.

The noise of the devices and the draft created by their rotors can also prove distracting, and there are safety concerns about being physically attached to drones that have high-speed rotors.

"To be totally honest with you, it's not something that you can right now test with people in a safe manner," says Feick. To keep participants safe, the team had fishing nets to catch the drones, he says.

In the future, quieter, safer drones will be needed for the design to become practical, says Feick. "There has been some progress in terms of blade-free drones," he says, which soundlessly fly around and levitate using ultrasonic waves. ▮ MS

Plants

'Unselfish' genes could help us to boost crop yields

Kismat Shrees

IDENTIFYING genes that make plants "cooperate" with their neighbours rather than compete with them could enable breeders to develop more productive crops.

Natural selection usually favours "selfish" plants that beat their rivals in the competition for light, space and nutrients. But crop breeders can boost overall yield by selecting plants with traits that are helpful to those growing nearby, such as shorter stems, less spread out leaves and compact roots.

Genetic analysis could be the key to discovering more of these cooperative traits that would enhance breeding programmes, says Samuel Wuest at the University of Zurich in Switzerland.

Wuest and his colleagues came up with a simple breeding experiment to identify how cooperative a plant's genetic make-up is. They grew specimens of thale cress (*Arabidopsis thaliana*) alongside neighbours that were genetically similar or dissimilar. This enabled them to determine which set of genes either promoted the ability to grow rapidly and competitively or the ability to grow cooperatively.

They discovered a gene with two variants, in which the less frequent, or minor, variant was strongly associated with cooperation. Plants with this variant collectively produced 15 per cent more biomass when grown in high-density situations than those carrying the other version of the gene.

This could be because plants with the minor variant didn't invade their neighbours' root zones with their own roots as much, allowing more equitable access to nutrients (*PLoS Biology*, DOI: 10.1371/journal.pbio.3001842).

Similar experiments with crop plants may help breeders find genes that promote cooperation and improve yields. ▮

Technology

Volunteer project uses GPS to spot North Korean missile test

Jeremy Hsu

THE NORTH KOREAN PRESS SERVICE/UPI/SHUTTERSTOCK

North Korea's missile launch on 18 November

GPS satellites could be used as a global monitoring system for detecting intercontinental ballistic missiles. The principle was demonstrated on 18 November, when researchers identified in satellite data the atmospheric disturbances caused by North Korea's largest intercontinental missile test yet.

Jeffrey Lewis at the Middlebury Institute of International Studies in Monterey, California, posted an animation showing the detection on Twitter. This was a big moment for the open-source intelligence project behind the detection, which has worked to find missile and rocket launches in this way for the past two years.

Volunteers at the project have developed computer software to detect disturbances in Earth's atmosphere by measuring signals travelling between GPS navigation satellites and ground stations.

"It would be wonderful if this could be a truly global network," says Tyler Nighswander at Theori, a cybersecurity company in Texas, who worked on the project.

Lewis had the idea of actively tracking missile and rocket launches through disturbances in the ionosphere – part of the upper atmosphere filled with charged particles. He asked for help making it a reality from the online open-source intelligence community, which aims to make better use of publicly available information for intelligence purposes.

> **"The researchers drew on studies showing how rocket launches can affect the ionosphere"**

Nighswander and Michael Nute at Rice University in Texas took up the challenge. They first had to find a global navigation satellite system that publicly shared data on at least an hourly basis, and opted to use Japan's GEONET system.

Next, the researchers created computer software to detect changes in the ionosphere. They drew on decades of previous studies by Kosuke Heki, formerly at Hokkaido University in Japan, and others showing how rocket launches can affect the ionosphere. The water vapour in rocket exhaust interacts with and depletes the ionosphere's charged particles, while related acoustic shock waves can push particles around.

The total number of charged particles can affect radio signals, with different signal frequencies passing through at different speeds. By measuring the precise delay between satellite signals on two different frequencies, it is possible to measure the number of charged particles and detect changes over time.

The researchers developed algorithms to identify these changes. The rate of false detection alarms is quite low because a large ballistic missile looks different from natural ionospheric phenomena, says Nighswander. But the method can still miss low and intermediate-range ballistic missiles with lower trajectories that don't leave a similar trail in the ionosphere, he says.

Using the Japanese data, this system can determine the time and rough geographic location of a missile or rocket launch in the region, but more data from multiple points of view would be required to reconstruct the flight path of a North Korean missile.

"I think this is very powerful," says Charles Lin at National Cheng Kung University in Taiwan. Lin has previously observed ionospheric disturbances associated with rockets such as the SpaceX Falcon Heavy, but he described the success in detecting a North Korean ballistic missile as "very impressive". ▮

Immunology

Universal flu vaccine shows promise

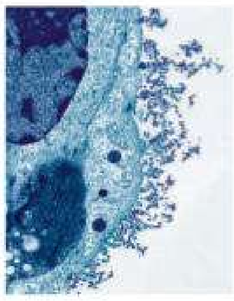
Mice given the experimental jab made antibodies against all 20 strains of seasonal influenza

Carissa Wong

AN EXPERIMENTAL vaccine has generated antibody responses against all 20 known strains of influenza A and B in animal tests, raising hopes for developing a universal flu vaccine.

Influenza viruses are constantly evolving, making them a moving target for vaccine developers. Annual flu vaccines are tailored to give immunity against a few specific forms of flu predicted to circulate each year. However, researchers sometimes get the prediction wrong, meaning the vaccine is less effective than it could be in those years.

Some researchers think that annual flu jabs could be replaced by a universal flu vaccine that is effective against all flu strains. Researchers have tried to achieve this by making vaccines containing protein fragments that are common to several influenza strains, but no universal vaccine has yet gained clinical approval.



Human cells infected with influenza virus, viewed with an electron microscope

STEVE GESCHMEISSNER/SPL

Now, Scott Hensley at the University of Pennsylvania and his colleagues have created a vaccine based on mRNA molecules – the same approach that was pioneered by the Pfizer/BioNTech and Moderna covid-19 vaccines.

These molecules contain genetic codes for making proteins, just like DNA. The vaccine contains mRNA encoding fragments of proteins found in all 20 known strains of influenza A and B – the viruses that cause seasonal outbreaks each year.

The strains have different versions of two proteins on their surface, haemagglutinin (H) and neuraminidase (N), which are targeted by immune responses. But even within one strain, such as H1N1, there can be slight variations in these proteins, so the version in the universal vaccine won't exactly match every possible variant.

In tests in mice, the team found that the animals generated antibodies specific to all of the 20 strains of flu virus, and these antibodies remained at a stable level for up to four months.

In another test, the team gave mice the universal flu vaccine or a dummy vaccine containing code for a non-flu protein. A month later, they were infected with either one of two variants of the H1N1 flu virus, one with an H1 protein that was very similar to the version of the protein coded for in the vaccine and one with a more distinct version.

All the mice given the flu vaccine survived exposure to the virus with the more similar protein and 80 per cent survived being infected with the more distinct variant. All of the mice given the dummy vaccine died around a week after infection with either variant.

The researchers also tested the universal vaccine in ferrets with similar results (*Science*, doi.org/jnt8). The findings suggest the vaccine could induce protective immune responses against emerging influenza strains.

"The animal results are promising, but it is hard to predict what the clinical trial data will bring"

"Definitely these animal data are promising and merit further exploration in clinical studies," says Albert Osterhaus at the University of Veterinary Medicine Hanover in Germany, but this is a first step. "Given previous studies with candidate universal flu vaccines in human trials, it is hard to predict what the clinical data will bring." ▮

Palaeontology

Predator was one of the first fast-growing vertebrates

A LARGE, crocodile-like animal that lived more than 340 million years ago was one of the earliest vertebrates to have a fast-growing phase in its youth.

Whatcheeria was an early tetrapod – one of the first vertebrates to have arms and legs instead of fins. At 2 metres long, it was one of the biggest carnivores of its era, and its anatomy hints that it snatched prey from the water by ambush, just like modern crocodiles. But how *Whatcheeria* reached such an impressive size for its time has been unknown.

The bones of *Whatcheeria* contain a record of the animal's growth, just as a tree's rings keep a timeline of its life history. Kenneth Angielczyk at the Field Museum of Natural History in Chicago and his colleagues looked at these microscopic clues in nine *Whatcheeria* femur bones.

They found that the animal grew much more rapidly early in life and reached maturity quickly compared with many of the earliest four-legged vertebrates to dwell at the water's edge (*Communications Biology*, doi.org/jntr). "When we came up with evidence of rapid, sustained growth, it was quite a surprise," says Angielczyk.

Illustration of *Whatcheeria*, a large predator that lived in the Carboniferous period

THE FIELD MUSEUM OF NATURAL HISTORY

Getting big quickly would have given *Whatcheeria* an edge. The tetrapod's growth spurt not only opened up a broader array of menu choices for the carnivore, but also helped *Whatcheeria* quickly get too big for other predators to eat.

Up until now, early tetrapods were thought to have grown relatively slowly throughout their lives, much the same way that many modern amphibians do. Fast growth was thought to be an evolutionary shift that came later among animals that were more reptile-like and laid their eggs on dry land.

The new work overturns that view. "It's an elegant study based on one of the best and most completely preserved early tetrapods we have," says Timothy Smithson at the University of Cambridge, who wasn't involved in the research. ▮

Riley Black

Space exploration

Paralympian joins new astronauts

European Space Agency plans to explore the feasibility of sending a "parastronaut" to space

Alex Wilkins

THE European Space Agency (ESA) has announced its newest astronauts, including the first ever astronaut with a physical disability.

John McFall, who is from the UK, had his right leg amputated after a motorcycle accident at age 19. He is a surgeon who has represented Great Britain and Northern Ireland as a Paralympic sprinter.

The other astronauts are engineer and pilot Sophie Adenot from France, aerospace engineer Pablo Álvarez Fernández from Spain, biomedical engineer Raphaël Liégeois from Belgium, doctor Marco Sieber from Switzerland and astronomer Rosemary Coogan from the UK.

"My research is in galaxy evolution, so I've always been interested in space and space science," says Coogan. "This is really taking it to the next level."

ESA also announced 11 astronauts who will enter its new astronaut reserve, which is made up of people who completed the selection process, but weren't chosen for full-time service.

"This selection was about talent and about capabilities to be a fantastic astronaut, but I'm also very proud that it happens to be a very good distribution of genders," ESA director-general Josef Aschbacher said at a press conference on 23 November.

After announcing last year that it would be selecting new astronauts for the first time since 2008, ESA received more than 22,500 applications from 25 countries, 17,126 of which were from men and 5397 of which were from women.

There were 257 applications specifically for the role of "parastronaut", which ESA confined to people with "lower limb deficiencies". This was defined as either a "single or double foot deficiency" through the ankle or below the knee, a pronounced leg length difference or a height below 130 centimetres.

The role of parastronaut isn't a guarantee for space flight, according to ESA, but instead is a "feasibility project" where ESA will assess spacecraft and procedural adaptations for a possible space mission.

The successful astronauts had to make it through six stages. After the initial screening, the first group of candidates went for a full day of psychological performance testing to see if they could cope with the stresses of space flight. This group was then whittled down to just over 400 people, who then went for more psychological interviews and group tests. Those who passed took medical tests and, if they passed, were invited to a final round of recruitment interviews.

"It feels as though we've been tested on everything imaginable really, from physics and maths skills to memory, psychology, interaction with others, medical, enthusiasm, everything I can think of," says Coogan.

The successful applicants will undergo a year-long basic training course at ESA's European Astronaut Centre in Cologne, Germany. ▮

ESA's newly recruited career astronauts and reserve astronauts

ESA - P. SEBIROT

Health

Specific brain markers found for ADHD in children

A STUDY of more than 7800 children has found that those with attention deficit hyperactivity disorder (ADHD) can have a smaller outer layer of the brain and specific neural connections not seen in those who don't have the condition. The findings suggest that brain imaging could help diagnose ADHD.

Brain features of ADHD have previously been identified in small studies. Now, Huang Lin at the Yale School of Medicine and her colleagues have confirmed that certain features involved in impulse control, short-term memory and concentration located in the prefrontal cortex are linked to ADHD. They did this by analysing MRI brain imaging data from more than 7800 children aged 9 or 10.

The researchers trained a machine-learning artificial intelligence to form links between brain characteristics and whether someone had ADHD. This involved giving it the brain imaging data of around 80 per cent of the children, including numerical data such as the size, surface area and neural connectivity between brain regions, along with their ADHD status.

When the trained AI looked at data from the remaining 20 per cent of participants, it was able to identify 60 per cent of children with ADHD and 56 per cent of children who didn't have ADHD. The results were presented at a Radiological Society of North America meeting in Chicago on 27 November.

> "We show that certain brain features linked to ADHD are distinct enough for an AI to make predictions"

"We show that certain brain features linked to ADHD are distinct enough for an AI to make predictions," says Lin.

"It is great having such a large sample, particularly with a high number of females with ADHD, who tend to be underrepresented in ADHD research," says Tim Silk at Deakin University in Melbourne, Australia. However, the predictive ability of the AI is little better than the toss of a coin, he says.

Still, being able to scan for brain signatures could make diagnosis of ADHD more objective, says Lin. ▮

Carissa Wong

Technology

Gliding sensors inspired by seeds biodegrade after use

Ananya

JAVAN cucumber seeds have inspired a gliding sensor that could be used for environmental monitoring, and then biodegrade, leaving no waste.

Ecologists use sensors to collect data on variables like temperature, humidity and pH to understand ecosystems. But if these sensors are left behind, the electronic waste can pollute the environment.

Now, Fabian Wiesemüller at the Swiss Federal Laboratories for Materials Science and Technology and his colleagues have fitted a biodegradable sensor to a glider that will also break down in soil.

The design of the device is based on the winged seeds of the Javan cucumber, which glide for long distances when they fall from high in the forest canopy.

The team made the glider out of starch paper, placing an actuator that houses a pH sensor at the centre. The sensor is essentially a coating of litmus, which changes colour to show the acidity of the soil where it lands. The actuator is made from cellulose fibres and gelatin, and is covered with a resin called shellac. It acts as a protective cover, and the material expands and opens to expose the sensor only at a certain level of humidity, which normally occurs when it rains.

Once a group of the gliders are released from a drone, they will spread over a wide area, says the team. In the experiments, the glider travelled for about 50 metres when released from a height of 10 metres (*Frontiers in Robotics and AI*, doi.org/jnkm).

The drone can then visually scan any colour change of the sensors to build a map of the area's soil acidity.

The team tested biodegradability by burying the gliders in soil in the lab. After just seven days, the wings had completely degraded. It would take about 100 days for the rest of the components to disintegrate, says Wiesemüller. ▮

Virology

A 48,500-year-old virus has been revived from permafrost

Michael Le Page

NATURE PICTURE LIBRARY/ALAMY STOCK PHOTO

Exposed, melting Arctic permafrost in Svalbard, Norway

SEVEN types of viruses that have lain dormant in the Siberian permafrost for tens of thousands of years have been revived. The youngest were frozen for 27,000 years, while the oldest was on ice for 48,500 years – making it the most ancient virus resuscitated.

"[This] is a world record," says Jean-Michel Claverie at Aix-Marseille University in France, who did the work with his colleagues. His team has previously revived two 30,000-year-old viruses from permafrost, the first of which was announced in 2014.

The team says the fact that all nine viruses remained capable of infecting cells shows that ancient viruses from melting permafrost are a threat to the health of plants and animals, including us.

While 48,500 years may be a record for a virus, several groups claim to have revived bacteria trapped in sediments, ice or salt crystals that are up to 250 million years old. However, it remains unclear whether the organisms are actually that old or are younger ones that contaminated samples.

The nine viruses Claverie's team has revived are distinct from all previously known ones, he says, so are very unlikely to be from contamination of the sample by modern entities. The team discounted several other apparently revived viruses because their genomes were too similar to known ones.

9

Number of ancient viruses that have been reawakened

It could well be possible to resurrect viruses that are much more than 48,500 years old, says Claverie. The deepest permafrost is up to a million years old. However, it is difficult to establish the age of ancient permafrost because standard radiocarbon dating doesn't work beyond 50,000 years.

The 48,500-year-old virus came from permafrost 16 metres below the bottom of a lake in Yukechi Alas in Yakutia, Russia. It is a type of pandoravirus – a giant virus that infects single-cell organisms known as amoebas (bioRxiv, doi.org/jnkg).

In fact, all the nine viruses revived by the team so far are giant, amoeba-infecting viruses because the team adds permafrost samples to cultures of amoebas and inspects them under a microscope for signs of infection, which shows the virus is "alive" and replicating.

If ancient, giant viruses remain infectious after being frozen for so long, other kinds will too, says Claverie.

Eric Delwart at the University of California, San Francisco, who has recreated plant viruses from long-frozen caribou faeces, agrees. "If the authors are indeed isolating live viruses from ancient permafrost, it is likely that the even smaller, simpler mammalian viruses would also survive frozen for aeons," he says.

That means there is a risk of ancient viruses infecting plants or animals, including people, if they defrost, says Claverie. This risk is being made greater by climate change melting permafrost, he says. "There are bacteria and viruses coming out every day."

While there used to be few individuals in the Arctic to be exposed to such infection threats, says Claverie, more people are moving there to mine resources such as gold and diamonds. And the first step in mining is to strip away the upper layers of permafrost. "There is a real danger," he says.

Delwart thinks the risk of an ancient permafrost virus triggering a pandemic is much lower than that from the viruses circulating in domesticated and wild animals, though. ▮

Environment

Mussel numbers have crashed in the river Thames

Matthew Sparkes

MUSSEL populations in the river Thames in the UK dropped by as much as 99 per cent between 1964 and 2020. Why isn't clear, but the researchers involved suspect it is down to the effects of pollution and invasive species.

To shed light on the long-term trend, Isobel Ollard and David Aldridge at the University of Cambridge replicated the earliest rigorous study available on these mussel populations, a survey on the Thames in Reading, Berkshire, dating from 1963 and 1964.

In 2020, the pair collected samples and found that the number of duck mussels (*Anodonta anatina*) per given area had decreased to just 1.1 per cent of 1964 levels. The painter's mussel (*Unio pictorum*) had fallen to 3.2 per cent of 1964 levels, and they found no living specimens of the depressed river mussel (*Pseudanodonta complanata*) at all (*Journal of Animal Ecology*, doi.org/jns6).

Mussels collected in 2020 were also smaller, reaching between 65 per cent and 90 per cent of the length they would have been in 1964 at the same age. This, coupled with lower numbers of the molluscs, means that annual biomass production by all mussels present had fallen in 2020 to just 7.5 per cent of 1964 levels.

Ollard says this will be having an impact on the ecosystem, because mussels provide important functions in freshwater environments, such as improving water quality.

Invasive species are a large reason for the decline of native species, says Ollard. While no zebra mussels (*Dreissena polymorpha*) and Asian clams (*Corbicula fluminea*) were found in 1964, she saw strong populations of both in the latest survey, but not enough to compensate for the drop in shellfish numbers. Pollution may be to blame for the overall fall, she says. ▮

Technology

Meta's board game-playing AI passes as human

Jeremy Hsu

AN AI that is an expert at the first world war strategy game *Diplomacy* can now participate in game conversations and negotiations without most human players realising they are talking to a machine.

The game of *Diplomacy* involves seven players competing for control over European territories. But there is also room for cooperation as players negotiate temporary alliances in coordinating movements and attacks.

Researchers at Meta, the parent company of Facebook, built an AI named Cicero that learned to play *Diplomacy* through trial and error and by mimicking what human players typically do. This previously allowed the AI to beat expert human players in a simplified version of the game that didn't involve negotiation.

The team has now added a language component to Cicero so that it is capable of interpreting and generating messages. The researchers started out with a pre-trained AI system capable of analysing language and further trained it on 12.9 million human messages from more than 40,000 games of *Diplomacy*. They also developed methods for filtering out nonsense from Cicero's messages.

Such language capability allowed Cicero to understand human intent from messages and use that information to inform its actions, says Emily Dinan at Meta. Cicero also used its strategic reasoning capability to generate messages that were linked to its goals in the game.

5277

Number of messages the AI sent over 72 hours of gameplay

The researchers entered Cicero anonymously in 40 games of *Diplomacy* hosted by an online league of human players. The AI sent 5277 messages to human players over the course of 72 hours of gameplay – and almost nobody wised up to the fact that they were communicating with an AI. Just one player voiced suspicion in a post-game chat that one of the AI accounts might have been a bot. Cicero ranked in the top 10 per cent of players across the games.

"What really impresses me is how the strategic reasoning and language models come together," says Julian Togelius at New York University.

One ongoing challenge for language AI systems is that they often replicate biases. For example, Cicero had a tendency to assume players were male. This issue of bias was further complicated by human players using aggressive or militaristic language specific to *Diplomacy*. The Meta researchers developed language filters that caught most toxic language generated by Cicero, although they didn't share specific examples of where things went wrong (*Science*, doi.org/gq9w2s).

Cicero's success came in an online version of *Diplomacy* where each negotiation turn is limited to 5 minutes. "Even though Cicero yields very promising results against the human players it faced, the short turn times of this game variant give Cicero an unfair advantage," says Georgios Yannakakis at the University of Malta.

It was still no mean feat for the AI to pass as human while outplaying most humans at the game. Cicero generally took an honest and helpful approach to negotiations, where many *Diplomacy* players use deception and lies – but that didn't mean the AI was naive.

"There are also situations where it may withhold strategically valuable information to help it achieve its objectives," says Dinan. ▮

HASBRO

***Diplomacy* is a board game that involves detailed negotiations**

Palaeontology

Oldest army ant found in amber

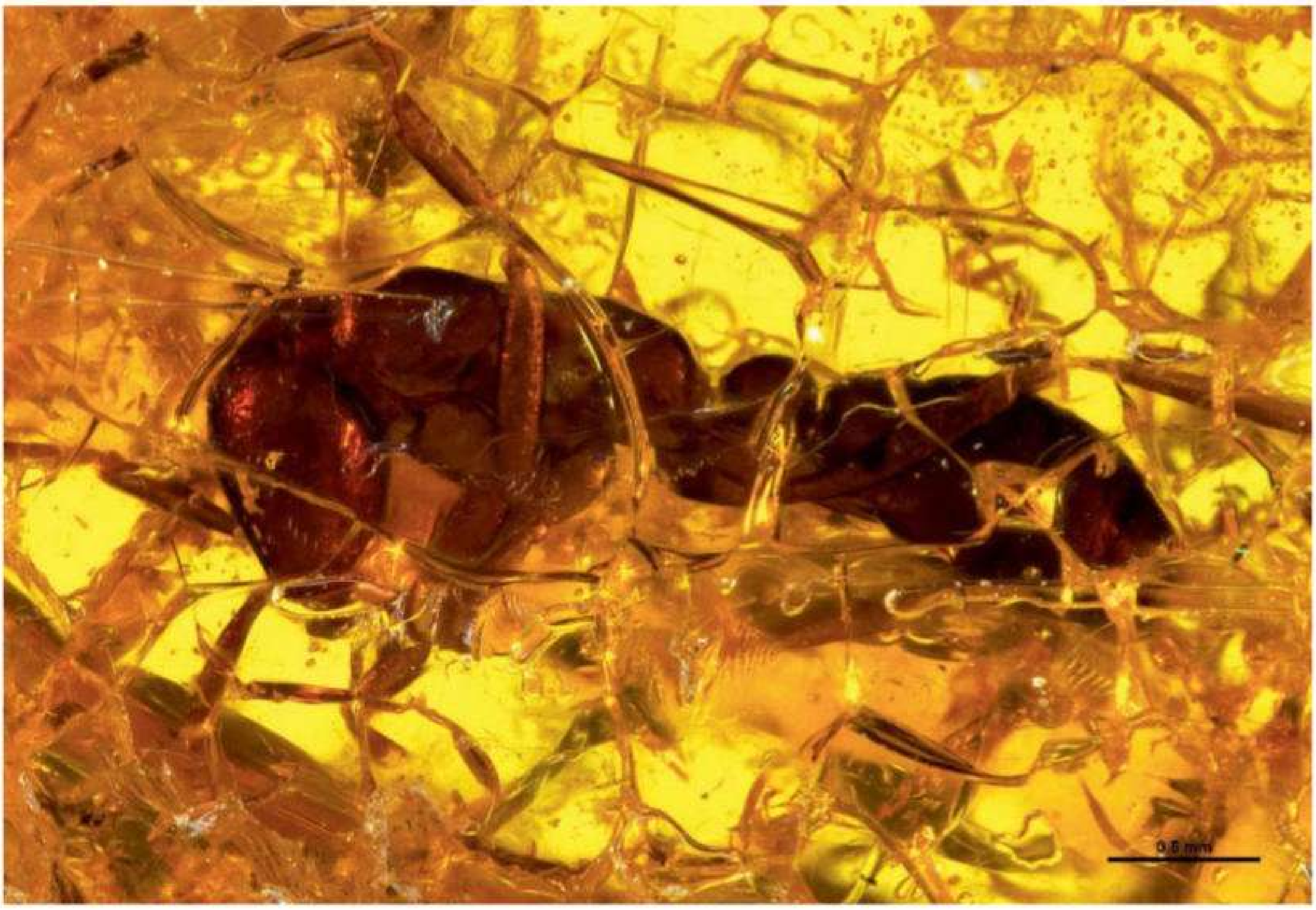
Surprise find in 35-million-year-old tree sap identified as a new species

Christa Lesté-Lasserre

THE world's oldest army ant has been identified in a block of 35-million-year-old Baltic amber. The unexpected discovery suggests that the blind, belligerent insects – now common in Africa and South America – once roamed the European continent.

Christine Sosiak at the New Jersey Institute of Technology was investigating amber-embedded ant fossils, stored at Harvard University since the 1930s, when she came across a specimen that appeared to be mistakenly identified.

Using photography and microscopic CT scans, Sosiak and her colleagues created high-resolution images and a 3D model of the well-preserved, shiny brown ant. They identified it as a new species related to army ants found in Africa today, which they named *Dissimulodorylus perseus* in honour of the Gorgon-slaying Greek hero (*Biology Letters*, doi.org/jng8).



CHRISTINE SOSIAK

Astronomy

Huge satellite is brighter than almost all stars

A TEST satellite for a future space-to-Earth mobile phone network is brighter than 99.8 per cent of stars visible to the naked eye. If a planned fleet of 100 additional satellites is as bright or brighter, astronomers are concerned it could severely impact ground-based astronomy.

In September, Texas-based firm AST SpaceMobile launched its BlueWalker 3 satellite to test beaming a cellular connection directly to mobile phones from space. BlueWalker 3 has a 64-square-metre reflective antenna, and the company has indicated that its future satellites, called Bluebirds, could be twice as large.

In the first 64 days after the satellite launched, astronomer Anthony Mallama and his colleagues tracked its visual brightness from Earth, using binoculars to look at the test satellite and compare it with stars of a known brightness. At its most reflective times – at sunrise and sunset – they found it had an apparent magnitude of +1.5 on a scale used by astronomers in which lower numbers denote brighter objects (arXiv, doi.org/jnkw).

"There are only 14 stars in the night sky brighter than magnitude +1.5," says John Barentine of Dark Sky Consulting, a company based in Tucson, Arizona, who wasn't involved in the work. "That means BlueWalker 3 under typical conditions is brighter than 99.8 per cent of all stars visible to the unaided eye."

AST SPACEMOBILE

The reflective antenna of BlueWalker 3 before its launch in September

The Bluebirds' reflectiveness at sunrise and sunset could transform the sky for casual stargazers as well as astronomers, says Aparna Venkatesan at the University of San Francisco, California. "These satellites will eventually be visible at higher altitudes above the horizon and for more of the night as they reach their planned higher final orbits," she says.

An AST SpaceMobile spokesperson said: "We're eager to use the newest technologies and strategies to mitigate possible impacts to astronomy. We are actively working with industry experts on the latest innovations, including next-generation anti-reflective materials."

Alex Wilkins

Biotechnology

Genetically modified tobacco plant makes cocaine in its leaves

Alex Wilkins

THE complex biochemistry that sees coca plants make cocaine has been unpicked and replicated in a relative of the tobacco plant. Recreating the process by modifying other plants or microorganisms could lead to a way to manufacture the stimulant or produce chemically similar compounds with unique properties.

Biochemists have tried to map out how cocaine is made by the coca plant for more than a century, both because of its unique structure and for its uses in medicine, most recently as an anaesthetic. Much of this process had been identified, but there was still a missing link between cocaine and a chemical precursor called MPOA.

Now, Sheng-Xiong Huang at the Kunming Institute of Botany in China and his colleagues have bridged this gap by identifying two enzymes involved in converting MPOA to cocaine.

The team then genetically modified a close relative of the tobacco plant, *Nicotiana benthamiana*, to make cocaine using these enzymes. It could produce about 400 nanograms of cocaine per milligram of dried leaf, roughly a 25th of the level in a coca plant (*Journal of the American Chemical Society*, doi.org/gq9dxr).

"The available production of cocaine in tobacco is not enough to meet the demand on a mass scale," says Huang, but the biosynthetic pathway could be assembled in organisms with large biomass and quick growth, such as the bacterium *Escherichia coli* or the yeast *Saccharomyces cerevisiae*, he says.

Using less-productive plants to make cocaine won't offer an advantage for illicit producers, says Benjamin Lichman at the University of York, UK. But transferring this mechanism to microorganisms could allow pharmaceutical firms to ferment it and avoid plant-based production, he says. ▮

Space

JWST spots chemical reactions in exoplanet atmosphere

NASA/JPL-CALTECH/ROBERT HURT; CENTER FOR ASTROPHYSICS–HARVARD &AMP; SMITHSONIAN/MELISSA WEISS

Chemical reactions occurred on the exoplanet WASP-39b

THE James Webb Space Telescope (JWST) has picked up on chemical reactions driven by starlight taking place in the atmosphere of a distant alien world for the first time, raising hopes the telescope could help identify exoplanets hosting life.

Many of the compounds in Earth's atmosphere, including some that are essential for life, didn't exist when the planet formed. Instead, they were the product of chemical reactions triggered by light from the sun.

These photochemistry reactions also occur in the atmospheres of almost all the other planets in our solar system and so were predicted to happen in exoplanet atmospheres. But until now, they had never been observed.

In August, JWST observations of the exoplanet WASP-39b, a 900°C ball of gas as massive as Saturn and wider than Jupiter, found the first evidence for carbon dioxide in an exoplanet atmosphere. But astronomers also spotted a strange bump in the signature of the planet's light, which suggested an unknown element or molecule was absorbing the host star's light as it passed through the planet's atmosphere.

Now, Katy Chubb at the University of St Andrews, UK, and her colleagues have analysed data on WASP-39b's light taken from four infrared instruments on JWST. "The large range of wavelengths covered by the four different instruments really allows us to build a complete as possible picture of this atmosphere as we can," says Chubb.

The team used a range of atmospheric models to mimic JWST's signal. Only models that included chemical reactions involving sulphur could reproduce the data, suggesting the bump was caused by atmospheric sulphur dioxide, says team member Éric Hébrard at the University of Exeter, UK. "We were very surprised because as soon as we each independently implemented the sulphur chemistry, it fit right away."

The levels of sulphur dioxide were far higher than they should be if the planet is made only from material created when the star system formed (arXiv, doi.org/gq9tf7 and doi.org/jnkn). The only explanation, says Chubb, is that light from the planet's star, WASP-39, caused a chain of chemical reactions in the planet's atmosphere and produced the sulphur dioxide.

"We haven't been able to probe such processes in the deep atmosphere before the JWST era," says Nikku Madhusudhan at the University of Cambridge.

Identifying photochemical reactions on WASP-39b may also help indicate whether the planet formed further out from its star and moved inwards, picking up material across its star system, or whether it formed at its current location and simply accumulated material there. Early observations of the oxygen-to-carbon ratio suggests it formed far away from its star, but more definitive data will be needed, says Chubb.

The find also bodes well for observing more compounds produced by photochemical processes, such as ozone on Earth, says Hébrard. "Even if [WASP-39b] is very different than what we have on Earth – it's hot, it's hydrogen dominated, you don't want to live there – having that first detection of a photochemical product is one way forward."

> "We haven't been able to probe such processes in the deep atmosphere before the JWST era"

Ultimately, such detections could help in one of JWST's mission goals: searching for signs of an exoplanet that could host life. ▮ AW

Fluid dynamics

Improved urinal reduces splashback

Design inspired by a nautilus shell produces far less splatter than standard models

Karmela Padavic-Callaghan

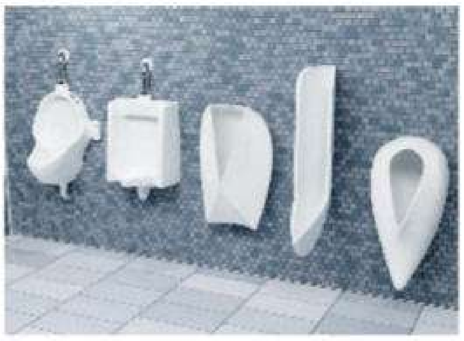
LABORATORY tests have helped physicists determine the ideal angle of urination to minimise splashback at a urinal, and have led to an elongated design for urinals that drastically reduces splatter.

"The idea originated exactly where you think it did. I think most of us have been a little inattentive at our post and looked down to find we were wearing speckled pants," says Zhao Pan at the University of Waterloo in Canada. "Nobody likes having pee everywhere, so why not just create a urinal where splatter is extremely unlikely."

To design a splash-free urinal, Pan and his team had to find the angle at which a stream of liquid hitting a surface produces the least splash. They solved this problem with a computer model that reproduced some previous observations of how dogs urinate.

They found that for the average human, the magic splash-reducing angle is approximately 30 degrees. Accordingly, they designed their test urinals so that, no matter what a person does, the impinging angle for urine is close to this value.

The researchers directed a jet of water onto urinals and measured the splatter using paper towels. They tested three experimental designs, a standard commercially available design and one similar to the urinal featured in Marcel Duchamp's artwork *La Fontaine*.



MIA SHI AT UNIVERSITY OF WATERLOO

The second urinal from the right was the optimal design

The researchers' number one design – second from right in the image above – was deeper and more elongated than standard urinals, allowing people of most heights to achieve the 30-degree angle. As its curvature is similar to a nautilus shell, the team nicknamed it Nauti-Loo. Standard urinals produced up to 50 times as much splashback as this new design.

A rounder design with a triangular opening (far right) performed twice as well as the Nauti-Loo in the splashback test, but wasn't favoured because it doesn't work for people of all heights. Pan's colleague Kaveeshan Thurairajah, also at the University of Waterloo, presented the team's results on 22 November at the annual meeting of the American Physical Society's Division of Fluid Dynamics in Indianapolis, Indiana. ▮

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Health

Dissolvable vaccine could prevent UTIs

A VACCINE tablet that dissolves under the tongue protects against urinary tract infections (UTIs) in mice. If it works in people, it could reduce the need to treat these infections with antibiotics.

Recurrent UTIs are often managed with daily antibiotics to prevent overgrowths of the bacteria that cause most UTIs. As an alternative, Sean Kelly and Joel Collier at Duke University in North Carolina and their colleagues have developed a vaccine that trains the immune system to recognise and fight UTI-causing bacteria by exposing it to three peptide molecules that are found on the bacteria's surface.

When tested in mice, the vaccine worked as well as high-dose antibiotics for preventing UTIs (*Science Advances*, doi.org/jnj4). **Alice Klein**

CARLOS PALACÍN

Technology

Prosthetic leg can help with stairs

A PROSTHETIC leg with motors that work like bike gears could let a wearer walk up stairs more easily.

Tommaso Lenzi at the University of Utah and his colleagues have created a fully powered prosthesis for people who don't have a leg from above the knee. Called the Utah Bionic Leg, it has an ankle joint and a big toe, which Lenzi says is a first for a powered prosthesis. This helps with stability. It also has a knee joint with a separate controller and battery.

The leg leverages the power of smaller motors to make trade-offs between speed and strength by internally changing the geometry of a joint and the point at which the motor's power acts on it. Its battery life could provide days on a single charge (*Science Robotics*, doi.org/gq956h). **Matthew Sparkes**

Zoology

Male great bustards may use plants to treat infection

MALE great bustards tend to eat more toxic plants during the breeding season, possibly as medicine to fend off sexually transmitted infections and so seem more attractive to potential mates.

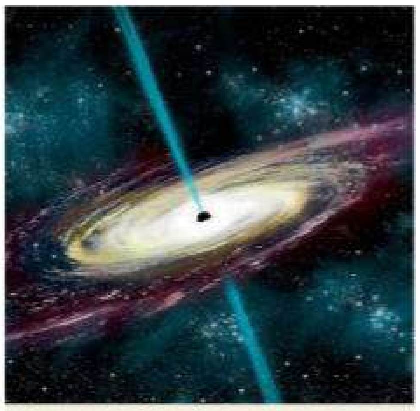
Male great bustards (*Otis tarda*), the heaviest flying animals alive today, expend great energy in elaborate feather displays to attract females. They also present their cloaca – the common opening for their digestive, urinary and reproductive tracts – to females, who appear to "examine" the orifice and even peck at it, possibly looking for signs of infection.

Only around 10 per cent of males successfully mate, so they might benefit from self-medicating prior to these examinations, says Luis Bautista-Sopelana at the Spanish National Research Council in Madrid. He wondered if that might explain why the birds prefer to eat common poppies (*Papaver rhoeas*) and purple viper's-bugloss (*Echium plantagineum*) – plants that are toxic to some extent – during the breeding season.

He and his colleagues acquired 17 extracts and essential oils from the leaves and flowers of each plant and placed individual extracts and oils in laboratory dishes containing organisms that commonly infect birds: a protozoan parasite (*Trichomonas gallinae*), a nematode worm (*Meloidogyne javanica*) or a fungus (*Aspergillus niger*).

They found that extracts and oils from the plants had notable effects on the pathogens. For example, certain flower extracts killed up to 98.6 per cent of the protozoa and up to 81.3 per cent of the worms (*Frontiers in Ecology and Evolution*, doi.org/gq9v2x). **Christa Lesté-Lasserre**

Really brief



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How blazars kick out particles so fast

Some supermassive black holes called blazars blast out huge jets of matter, and we may now know how the particles in those jets reach such high energies. X-ray space telescope observations suggest shock waves created through turbulence in the jets are accelerating the particles (*Nature*, doi.org/jnjv).

Seagull wing colour helps them glide

The dark colours on the top of the wings of some gulls change the temperature of the surrounding air, which may help them glide. While albatrosses use wing shape as well as colour to boost gliding, the colouration of gulls may compensate for their stubbier wing shapes (*Communications Biology*, doi.org/jnjw).

Sugar mix crafts tiny patterns

A sugar mixture similar to hard candy studded with tiny metal discs or rings has been used to create patterns on microscopic objects. Because sugar isn't toxic, the method could potentially be used for manufacturing microrobots and nanoparticles that enter the human body (*Science*, doi.org/jnj8).

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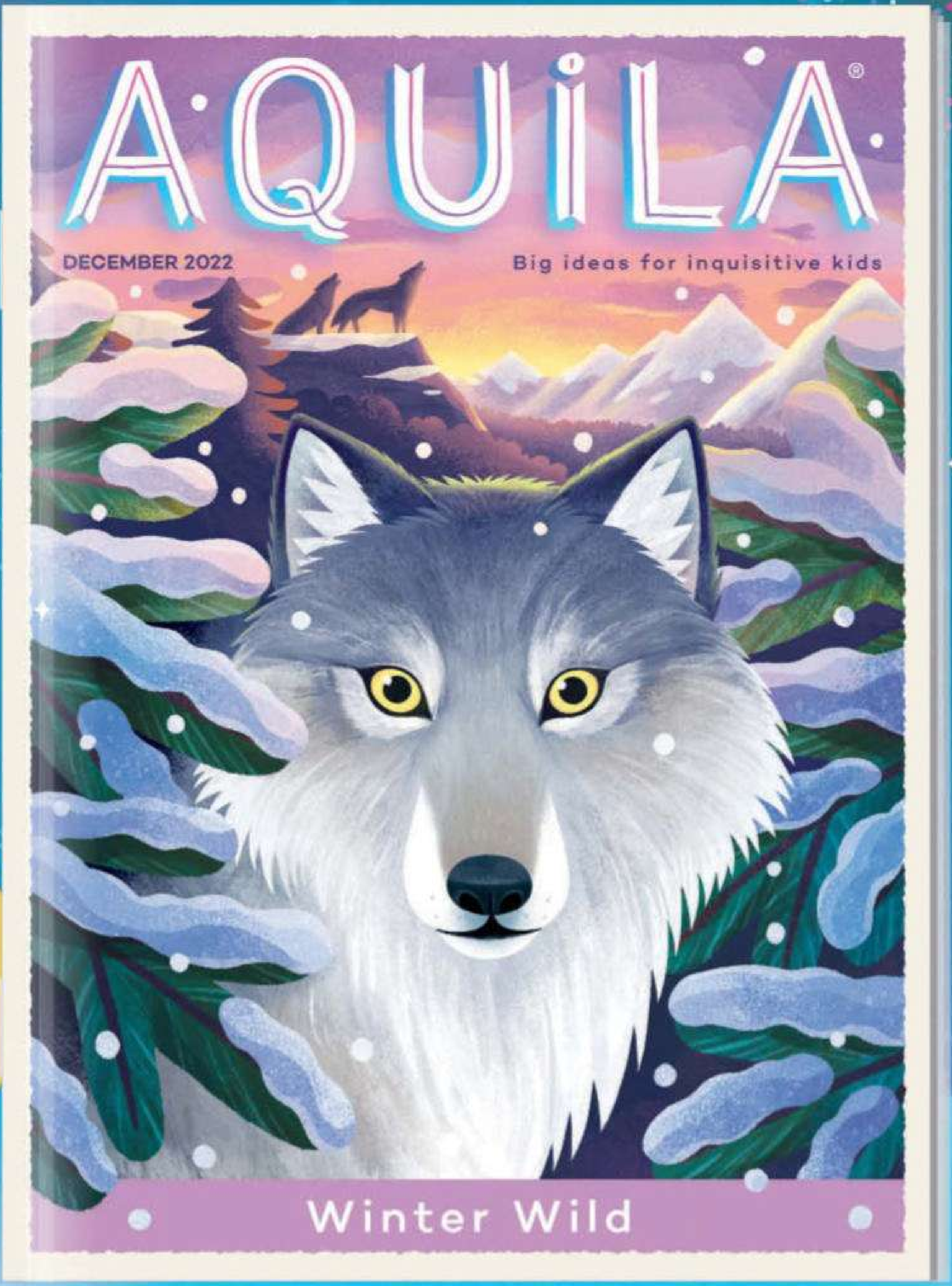

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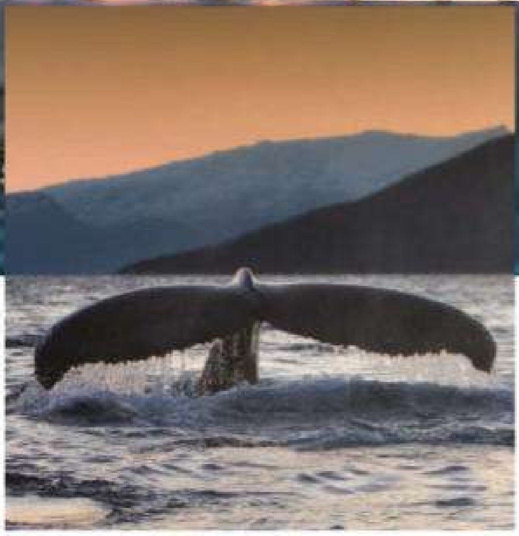

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- Two marine safaris exploring fjords, glaciers and abundant wildlife.
- Accompanied by *New Scientist*'s Rowan Hooper.
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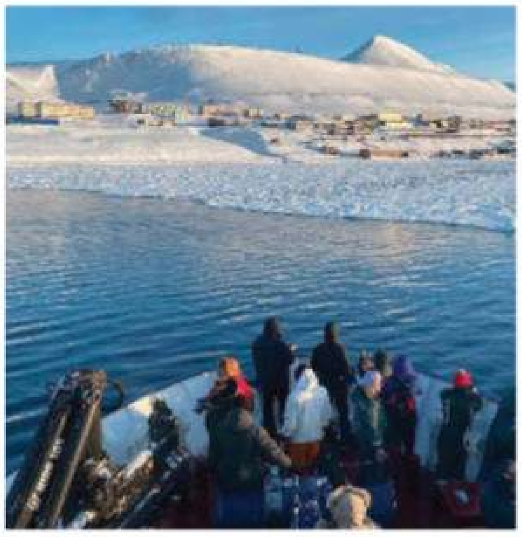
- Discover the Svalbard archipelago by land, sea and air.



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Comment

Calling for justice

The push for climate reparations is gaining traction post COP27, but voices from the Global South must unite, says **Zareen Zahid Qureshi**

MICHELLE D'URBANO

PAKISTANIS today exist amidst destruction. A third of my country is underwater, over 1000 people have been killed and damage worth $30 billion adds to crippling economic woes. This is all for a crime we didn't commit.

We aren't alone. Across the African continent, millions of people are living through the pangs of a postcolonial trauma that resurfaces with every drought, destroyed home and refugee.

All of us in the Global South (a term for lower-income, often decolonised, nations mainly in the southern part of the world) demand the same thing: relief. The push for loss and damage payments, also known as climate reparations, has gained momentum like never before. We have inherited a scorched Earth. The time for justice has come.

The developments at the COP27 summit resulted in a historic agreement to set up a loss and damage fund. It was a landmark success for the Global South – until we read the fine print. So far, the US and the UK – enriched by years of exploitation and high levels of carbon emissions – have yet to pledge a dime to the fund. After all, contributing to it is voluntary.

Countries like Denmark and Belgium will pay climate reparations, though it could be argued that this amount doesn't even begin to cover the losses incurred by the Global South during colonial rule.

In fact, it will be a year before we learn where the funds will come from and who will receive them. This makes it a proposition sadly reminiscent of the $100 billion pledge to lower-income countries for climate change adaptation at COP26, which has yet to materialise, let alone meet the $525 billion in climate change-related damage incurred by just 55 countries in the Global South in the past 20 years.

It is this ambiguity and lack of commitment that has proved that those of us in the Global South can't pin our hopes for survival on the world's wealthiest setting off to an Egyptian resort on private jets. If we have learned anything from COP27, it is that lower-income countries need to take more drastic measures when lobbying to ensure their survival. No one else seems very concerned.

Loss and damage might have had some success at the summit, but action on emissions and fossil fuel consumption didn't materialise. Meanwhile, initiatives like Global Shield – proposed by G7 nations and intended to help fund low-income countries in the event of climate disaster – put climate financing in the hands of the private sector, essentially acting as an insurance policy against environmental damage. Of course, nations like Pakistan pick up the premiums.

Choosing to skip COP27, Greta Thunberg lamented the lack of "moral and political leadership on the climate crisis". Perhaps it is time for the Global South to fill these gaps. For instance, faith-led environmentalism made waves at the R20 summit of faith leaders in Indonesia, where Muslim World League secretary general Mohammed Al-Issa called for the international community to engage faith leaders in pioneering a global opinion shift on climate action, driven by moral leadership.

Still, symbolic leadership, while powerful, won't compel high-income countries to pay their dues. It is also time to consider political and economic action. The masses of inexpensive labour that enriches high-income countries is in Africa, Asia and South America. Why not mobilise the collective leverage of the G77 – which broadly covers the Global South – to demand reasonable conditions for climate justice?

The voices for justice in the Global South must remain loud and united long after COP27. Centuries of exploitation, followed by apathy and indifference, are condemning us to extinction. But we don't owe anyone the favour of slipping away quietly. ▮

Zareen Zahid Qureshi is manager of Poverty Eradication Initiative in Pakistan

No planet B

Banding together A life-changing visit to a Ugandan research project on banded mongooses has shown me how international collaboration is vital for conservation, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

I AM writing this in Uganda, during a visit to a research project on banded mongooses in Queen Elizabeth National Park. It is a privilege to be here – the wildlife is astonishing, the people I've met wonderful and the scenery incredible. You may know that my wife Clare died recently. This trip is about getting stories, but it is also helping me to deal with my loss. Life-affirming doesn't do it justice.

Uganda is proud of its wildlife, and rightly so. The mission of the Uganda Wildlife Authority is to preserve biodiversity for the people of Uganda – and the global community. Long may it continue. This is what a properly biodiverse landscape looks like. For someone from a nature-denuded country like the UK, being here offers a glimpse of what the world must have looked like before we declared war on the natural environment in a quest for unlimited prosperity. Uganda is reaping the rewards of its efforts by attracting international eco-tourism. It costs serious money to visit the parks. But the beer is still cheap and the food is too.

However, Uganda is also on the front line of climate change. The rainy season ought to have ended by now, but hasn't. A waiter in the nearby safari lodge told us that it used to rain once a day for a couple of hours. Now it rains many times a day, often biblically, and at unpredictable times. A few days ago we visited the world-famous Kyambura gorge, part of the East African rift system, a landscape created by tectonic activity. After a 3-hour trek through dense jungle in search of chimpanzees, we had to turn back because the river was unusually swollen. Crestfallen, we walked back. But the despondency didn't last long. We saw the chimps near the car park.

The national park also has problems with invasive species. According to warden Raymond Kato, 40 per cent of the park is being swallowed by non-native plants and efforts to eradicate them have failed. A huge recent decline in an antelope called the Ugandan kob may be caused by shifts in vegetation. The mongooses are also challenged by the denser bush.

Of course, I had to fly here from the UK. So did the two people I came with, mongoose researchers from the University of Exeter's campus in Penryn, Cornwall. I haven't flown long-haul for many years and I feel guilty about my contribution to the climate crisis.

> "A visit to Uganda from the UK gives a glimpse of what the world was like before we declared war on nature"

This kind of long-haul flight is a hot topic among researchers in Uganda. Universities in the UK and elsewhere are increasingly discouraging staff and students from taking them. Ecology undergraduates used to be offered field trips to Borneo, Costa Rica and other far-flung places. Now, they mostly go to Europe.

The mongoose project – which over the past 27 years has made groundbreaking discoveries about the evolution of co-operation and conflict in social species, with direct relevance to humans – wouldn't be possible without long-haul flights. The project is run on a day-to-day basis by Ugandan scientists and field assistants. But the research funding, publications and scientific ideas come from the UK. To keep the project running, the principal investigators have to visit a couple of times a year, not least to discuss with field workers what hypotheses to test next.

The lead scientists will keep on flying here. But the next generation of Western field biologists is increasingly being denied the opportunity to work in places like Uganda. Aspiring conservation biologists need to visit the places where nature remains at baseline levels or they can't fully understand their subject. But anecdotally, I hear that Western research funding is increasingly focused on local projects and that scientists' horizons are narrowing.

This isn't just bad for European and North American scientists, but also for researchers in places like Uganda. There is no doubt that Ugandans could do the work independently, but their education system and scientific infrastructure are still in need of development and money. There aren't the facilities here to do DNA sequencing, for example – samples crucial for the mongoose project have to be sent to Europe.

A lot of this is about how things look rather than how things really are. Academic institutions should take the lead on important social and environmental issues such as carbon emissions, but scaling back long-haul flights to important research projects is ultimately counterproductive.

Carbon offsetting is imperfect, but when done properly it can be used to make long-haul flights net zero – I'll do this once I'm home. But nothing can offset the loss of international conservation biology collaboration where biodiversity still exists.

For me, the experience has been invaluable and life-changing. Uganda, the pearl of Africa, I salute you. Thank you for letting me visit your country. My horizons are now as broad as your skies. ▮

Graham's week

What I'm reading
Birds of East Africa *by Terry Stevenson and John Fanshawe.*

What I'm watching
Wildlife.

What I'm working on
My post-Clare life as a globetrotting reporter.

This column appears monthly. Up next week: Annalee Newitz

CONFLICT APPEAL

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

HELP US DELIVER MEDICAL CARE BEYOND THE FRONTLINES

An MSF medic treats a patient onboard the medical train. Photograph © Andrii Ovod/MSF

CHRISTOPHER STOKES IS COORDINATING MSF'S MEDICAL WORK IN UKRAINE

23 October 2022

"On 10 October I had just left the train station in Dnipro, eastern Ukraine, when the car started shaking. A second later, we heard the blast from the first missile. By the time we reached the office, we'd felt four more shockwaves from strikes. Since then, there have been regular waves of bomb attacks targeting infrastructure and civilian areas.

We're now gearing up for the possibility that the electricity will go off across Ukraine as a result of these ongoing attacks. That will have drastic knock-on effects on hospitals, healthcare and people's lives. People are heading into winter with the risk there will be no electricity, heating or hot water.

We're doing our best to prepare. We're helping a number of hospitals near the frontline get ready. We're running mobile clinics in areas previously under Russian occupation where people have had no access to the medicines they need for months. MSF operates a specially designed medical train that evacuates patients from near the frontlines of the fighting to safer areas and we're looking at ways to keep that running, even if the electricity fails. It's been kitted out with an intensive care unit and inpatient carriages. To date, we've evacuated 1,851 patients in 60 trips, most of them suffering from blast injuries and shrapnel wounds.

Last weekend we carried one family on the train who needed to be evacuated from the war zone. They had returned to their home in Nikopol on 5 October after having fled the war months earlier. On 6 October, their house was hit by a shell. One of the daughters was badly injured and ultimately had to have both legs amputated. She was only six years old.

The Ukrainians are doing the bulk of the medical work in this war. Our role is about filling the gaps. With these latest attacks, people's medical needs are growing, and it's vital we are here."

MSF'S WORK IN CONFLICTS

In conflicts around the world, MSF teams are working around the clock to treat trauma injuries, conduct surgeries and provide lifesaving medical care to the victims of bombings and indiscriminate attacks.

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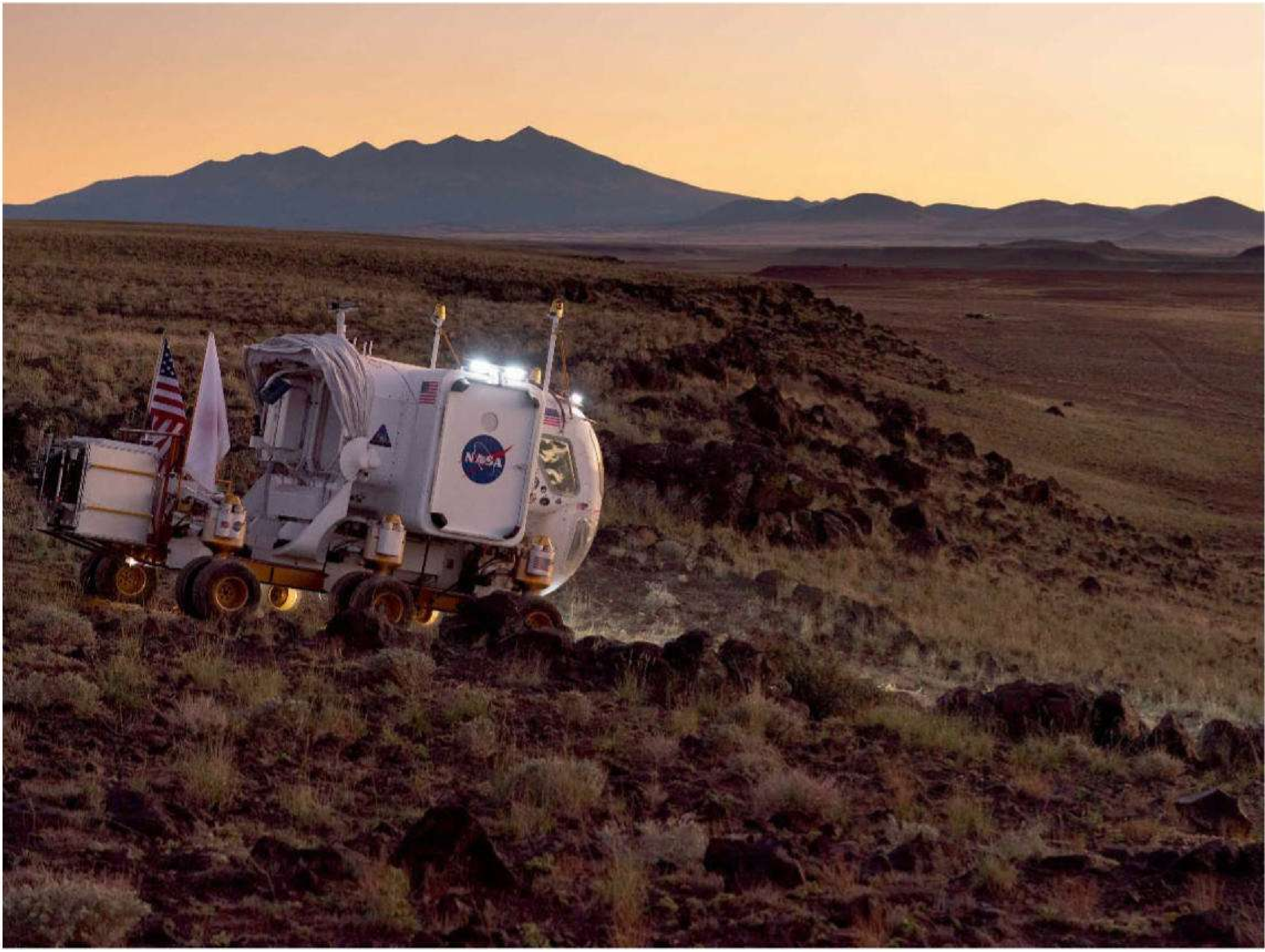

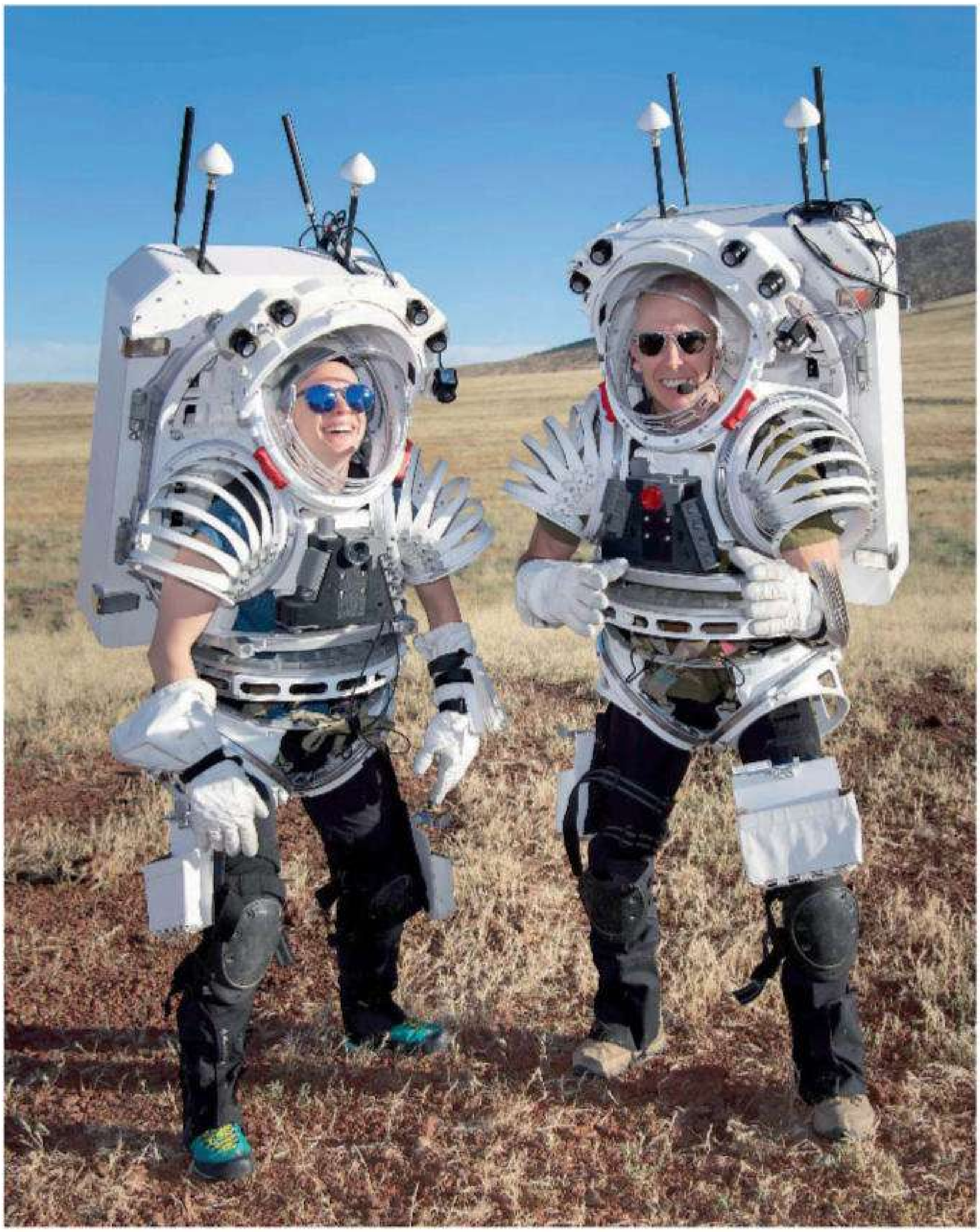

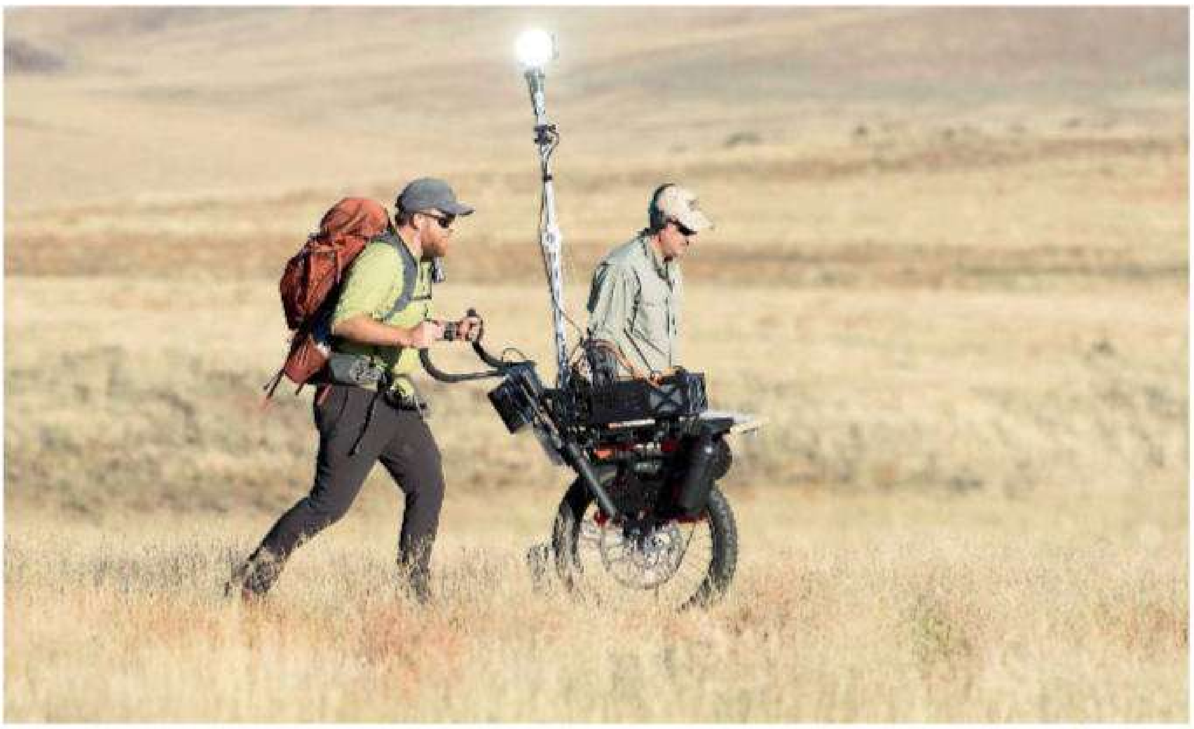

Dress rehearsal

Photographer Bill Stafford, NASA – Johnson Space Center

DEEP in the Arizona desert, astronauts are learning how to walk on the moon.

On 16 November, an uncrewed SLS rocket launched to lunar orbit, the first of many missions in NASA's Artemis programme. Also undertaken were two Earth-based operations, the Joint EVA Test Team (JETT3) and the Desert Research and Technology Studies programme (D-RATS), both designed to replicate aspects of future moon landings and help NASA engineers design the technology, protocols and tools to enable astronauts to do science on the lunar surface.

JETT3 mimicked the planned 2025 Artemis III mission to the moon's south pole, where astronauts will face challenging lighting conditions. The team operated at night, using a huge lighting rig to emulate the sun. New spacesuit technologies and sampling tools were used during the mock moonwalks, testing the ability of astronauts to conduct geological work in tricky terrain.

D-RATS tested pressurised rover technology that will allow astronauts to explore a wider lunar area. Ultimately, this feeds into NASA's goal of having a sustained human presence on the moon and, one day, on Mars.

Pictured clockwise from top right are: NASA astronauts Zena Cardman and Drew Feustel; a NASA team pushing a cart that simulates lunar lighting shadows; Cardman and Feustel during a simulated moonwalk; Japan Aerospace Exploration Agency D-RATS crew Yusuke Yamasaki and Akihiko Hoshide on a simulated moonwalk; and a D-RATS crew driving a pressurised rover prototype.

David Stock

Editor's pick

Could a cyclical universe trump the multiverse?

19 November, p 46

From Nigel Tuersley, Wardour, Wiltshire, UK

In your interview with Roger Penrose, he points out that "nobody knows where the fundamental constants of nature come from". The sheer improbability of their being so finely tuned for life has given rise to the multiverse hypothesis where, by a process you might call cosmological selection, life and consciousness only come to exist in universes that have "Goldilocks" constants. This requires that there are a large number of universes and, by random chance, one or more of them have the right values.

This prompts the question: why has the debate between an ever-expanding versus a cyclic universe focused on space rather than time? An ever-expanding universe can only do so once, in contrast to a cyclic one where, to use Penrose's terminology, if the constants "get jumbled up" between aeons, there is a higher probability of life-supporting values emerging.

All other things being equal, that favours a cyclic cosmology, multiverse or not.

Let the oil giants fund loss and damage payments

19 November, p 8

From Chris Lee, Stokesby, Norfolk, UK

Your article discusses the possibility of "loss and damage" payments by higher-income nations to lower-income ones suffering as a result of climate change. I fully support such reparations, but suggest they should be paid by fossil fuel firms.

These companies continue to plan expansion and further damage, have made huge profits from polluting our atmosphere and, in some cases, have funded campaigns to obfuscate their involvement and culpability. Plus, some have received large state subsidies for many years.

Why we may never get to grips with climate change

12 November, p 7

From Lloyd Timberlake, Ridge, Maryland, US

Almost all coverage of climate change ignores the horrendous reality that we will not and cannot manage this challenge. This is because we won't make major sacrifices for future generations, whose interests have little to no place in our institutions, especially our legal systems.

It is in neither the political nor economic interest of political leaders to act in favour of future people, who don't vote or spend, a truth that will damn humans to countless millennia of a climate that is hostile to our activities. This is a truth that will remain constant for generations, no matter how damaging the effects of climate change become. So we merely pretend, year after year, to care and to act in earnest, which is why there have been 27 COPs, rather than just one.

World population isn't sustainable as it is

12 November, p 14

From Geoff Harding, Sydney, Australia

If only sustainability in a world of 8 billion people were determined solely by food considerations. In fact, the desire to raise the standard of living to an acceptable and fair level will place impossible strains on many resources. Good-quality housing, clothing, personal transport and consumer goods, not to mention clean air and water and reliable green energy, should be available to all.

It is often said that for all to live like well-off Westerners, the resources of at least three Earths would be required, in which case a stable population of 3 billion may be barely sustainable.

Let's just scrap daylight saving instead

12 November, p 13

From Talia Morris, Cape Tribulation, Queensland, Australia

In your article on daylight saving, you suggest that by making daylight saving permanent in the US, excess human and deer deaths caused by the annual shift in clocks could be eliminated. This is possibly true, but I think eliminating daylight saving altogether would be a healthier and more sustainable option. It is very likely that both species would quickly re-adapt to the diurnal cycle that was, after all, normal on planet Earth for its entire history until extremely recently.

Red street lamps may not be so great, after all

Letters, 19 November

From Eric Kvaalen, Les Essarts-le-Roi, France

Two recent letters have advocated using red LEDs for street lighting. There are two reasons not to do this. First, sodium lights are being replaced by LEDs because LEDs can give a white light that helps people to see things better at night, especially in their peripheral vision. Second, our eyes aren't as sensitive to red light as they are to green or blue light, for the same amount of energy, in dim situations, such as under street lighting. Red LEDs, therefore, probably don't provide as much light per watt as the white ones.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT will be delayed

Mealworms are an answer to 'compostable' plastics

12 November, p 16

From Andrew Kadir-Buxton, Hatfield, Hertfordshire, UK

I read your report on problems with compostable plastic. A friend of mine tried to compost such plastic and found it didn't break down. I suggested adding some mealworms to his compost and the plastic was soon eaten. This is scalable, and perhaps the adult mealworms could be turned into pet food at the end of the process.

Time to pull the plug on big money for fusion

22 October, p 38

From Alec Mitchell, Vancouver, British Columbia, Canada

How is it that fusion research gets so much positive PR? I know that any research programme requires an element of optimistic taking of chances, but this whole field has the aroma of a lost cause about it – and yet we are still throwing money at fusion projects.

How many clean energy production and storage facilities, using proven technology, could we have bought instead? It is high time we consigned fusion research to the low-priority, low-funded fundamental research file until such time as we can't think of better things to fund.

No drought needed for industrial revolution

5 November, p 20

From John McIntosh, Birkenhead, Merseyside, UK

You report the view that drought may have started the industrial revolution and the move away from water power. I don't buy it. The switch to steam didn't need a drought. Water power required a factory near a river. Steam power allowed factories anywhere, with flexible and expandable layouts. Once the economics became similar, no one would build a factory that used water power. ▮

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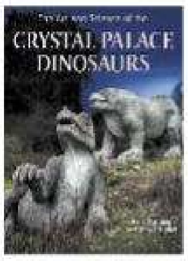
A feast for the soul

From concrete dinosaurs to human evolution, exquisite plants to space travel, **Simon Ings** picks the best non-fiction to give to those you love this year

MIKHAIL MIKHEEV / EYEEM

TRAWLING through the year's science books is a good way to restore perspective. They tackle everything from imagining the new world that emerged after the dinosaurs were wiped out to understanding our own place in nature by exploring the woods, and from extending our senses to the value of emotions. Enjoy our selection: many of our picks were reviewed in these pages, but they are all terrific reads and will make great gifts.

From dinosaurs to plants



It is just as well that the world is full of surprises because the human appetite for novelty is insatiable. Barely 10 years after naturalist and palaeontologist Richard Owen coined the word "dinosaur" to describe the giant fossil lizards, a pleasure garden was exhibiting them at scale – rendered in Victorian concrete.

Our hunger for the past is captured twice over in Mark Witton and Ellinor Michel's *Art and Science of the Crystal Palace Dinosaurs* (The Crowood Press), which introduces us to those magnificent beasts and their talented interpreters. Reflecting on the fragility of the models still gracing London's Crystal Palace Park, *New Scientist* concluded that "a record this detailed – and so charming – is long overdue".

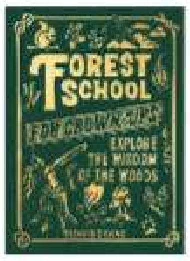
All good things must come to an end, alas, and the spectacular disappearance of the dinosaurs – incinerated by an asteroid strike – is brilliantly depicted in the early, apocalyptic chapters of Riley Black's *The Last Days of the Dinosaurs* (St Martin's Press). Even more impressively, Black shows how a new world emerged from the wreckage. "It is," wrote *New Scientist*, "as if she had set up camp in the very heart of the valley that best captures the catastrophe and its aftermath."

This wasn't Earth's first extinction event, nor will it be its last. Oliver Milman's anatomy of *The Insect Crisis* (Atlantic Books) warns of a catastrophic population decline among what he calls "the tiny empires that run the world", in an account that fully captures their sheer extraordinariness.

Andreia Salvador, a curator at London's Natural History Museum, performs much the same service for molluscs. The mind boggles to think how she whittled the museum's collection of 8 million-plus specimens down to the 121 in *Fascinating Shells* (University of Chicago Press).

At least she had a drier time of it than Chris Thorogood, whose book *Chasing Plants* (University of Chicago Press) promises to propel the reader through rainforests, swamps and mountains in pursuit of Earth's vegetal wonders. What's more, he supplements these death-defying adventures with his own wonderful illustrations and paintings.

Wild at heart



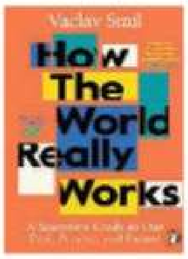
Discoveries are thrilling, but understanding our own place in nature can turn out to be a source of even deeper satisfaction. After 25 years spent teaching children the ways of the countryside, Richard Irvine finds his approach to outdoor education is in demand. His *Forest School for Grown-Ups* (Head of Zeus) lets us all explore the wisdom of the woods.

Part of his idea, of course, is that the better we understand something, the more we will care for it. But care can also lead to understanding. Take the fascinating *Exotic Vetting* (William Collins), where wildlife surgeon Romain Pizzi explains what we can learn about animals of all sorts from the operating table.

In *Sexus Animalis* (MIT Press), natural history researcher Emmanuelle Pouydebat finds lessons of another kind as she peers through the keyhole of animal sexuality. In justifying her subtitle "There is nothing unnatural in nature", she reminds us about the sheer breadth and diversity of animal behaviours, including our own.

Our complex cultural evolution puts us at a huge advantage to other species, which is why some of the largest and prettiest are fast-disappearing. In *Tickets for the Ark* (Profile Books), Rebecca Nesbit argues that our conservation efforts should focus on food webs and biospheres, more than on individual animals and plants, no matter how cute. After all, in the future, surely we would prefer to be part of a living planet than visitors to a petting zoo?

Under the hood



Environmentalist Vaclav Smil has spent a lifetime revealing truths about how our society is shaping the environment. In *How the World Really Works* (Viking), he reminds us that construction, energy and food production are essential activities that we fail to understand at our peril. *New Scientist* relished this "grumpy, pugnacious account" that was "intellectually indispensable in the run up to this year's COP27 climate conference".

Why is *Homo sapiens* hard-wired to tinker and consume on such a scale? Clues are to be found in *Life as Told by a Sapiens to a Neanderthal* (Scribe). This charming book was assembled from notes Juan José Millás took as he followed archaeologist Juan Luis Arsuaga across ancient and modern Spanish landscapes, as well as from their conversations. *New Scientist* said it was about "curiosity and enquiry itself… and an exaltation of the fact humans can wonder at all".

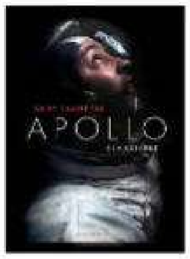
Elise Vernon Pearlstine's *Scent: A natural history of fragrance* (Yale University Press) explores that sense of wonder through smells. *New Scientist* was struck by the insights of this wildlife biologist who changed careers to become a perfumier specialising in scents that originate in nature.

> "It is just as well that the world is full of surprises because the human appetite for novelty is insatiable"

And we don't just enjoy the world, we give that enjoyment meaning. Evolutionary anthropologist Anna Machin's *Why We Love* (Weidenfeld & Nicolson) explores the science of our love relationships – with pets, football teams, religion and even smartphones.

Michelle Drouin's *Out of Touch* (MIT Press) offers a survey of the same territory, after covid-19. The psychologist challenges the idea that technology can ever "stand in" for activities rooted in society and biology.

Seen, unseen, unseeable



Of course, not every natural wonder is accessible to the senses. Two handsome volumes capture natural wonders far beyond Earth. The digitally restored images in Andy Saunders's *Apollo Remastered* (Particular Books) bring NASA's moon voyages to life as never before, while Piers Bizony's *NASA Missions to Mars* (Quarto) offers readers a sumptuous visual introduction to the Red Planet.

Armchair space travel is a passive business, but Kimberly Arcand and Megan Watzke give their readers plenty to do in *Stars in Your Hand* (MIT Press), their guide to 3D printing the cosmos.

Understanding reality has prompted ever stranger claims. In *The Matter of Everything* (Bloomsbury), physicist Suzie Sheehy describes 12 experiments that changed our world: from the detection of X-rays and the first subatomic particle to the 2012 confirmation of the Higgs boson. *New Scientist* said her book was "accessible"and "vividly described".

The stranger the universe turns out to be, the wilder the explanations. In *Quantum Steampunk* (Johns Hopkins University Press), physicist Nicole Yunger Halpern looks to steampunk to explain quantum thermodynamics, exploring questions such as can quantum physics revolutionise engines.

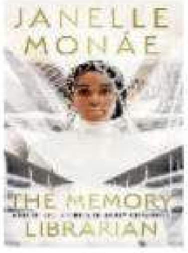
No round-up can do justice to all the scientific literature produced in a year, but subscriptions to *New Scientist* and its *Essential Guides* might. Make 2023 your year of intellectual adventure! ■

Simon Ings is a novelist and science writer

Spotlight on sci-fi

Uncertainty, dystopia – and hope. This is the sci-fi to share this year, says **Sally Adee**

EVERY era of science fiction reflects its times. Iconic 1950s sci-fi was all lone male heroes and alien encounters. In 2022, uncertainty and fluidity rule, as we struggle to find a way out of a polycrisis of our own making, armed only with hope. Buckle up for the year's best sci-fi.



"We already believed in the infinite web, so why not hard-wire an eye to each of its strands?" And that is how a fascist AI called New Dawn takes over in Janelle Monáe's *The Memory Librarian* (HarperCollins, pictured). This conceit anchors the tales in her Afrofuturist-inflected book, written by the polymath with a team of luminaries. The stories are an uneven mix, but the best are unforgettable.

The way technology contorts our inner lives is the subject of a domestic dystopia that verges close to literary sci-fi. Joma West's *Face* (Tordotcom) looks at how the perverse incentives of social media create a sousveillance state at odds with the alleged democratisation of policing.

Social terrors also suffuse Ling Ma's fantastical book of short stories, *Bliss Montage* (Text Publishing), which takes us on a safari of strange beasts, including our best friends, boyfriends and husbands.

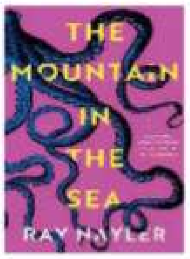
David Yoon's *City of Orange* (Putnam) also twists familiar tropes into the unfamiliar in his study of how whole worlds can end while civilisation goes on. For a lighter nihilism, try *Glitterati* (Titan Books), Oliver Langmead's brutal satire of the influencer industry, with a surprisingly poignant ending.

The worst outcomes are built on the most tempting myths. Edward Ashton's *Mickey7* (St Martin's Press) is a study in reading the fine print when hot technology beckons.

This theme also pervades *Valuable Humans in Transit and Other Stories*, a collection self-published by Sam Hughes (who goes by qntm) that contains his groundbreaking tale *Lena* and a new sequel.

Kameron Hurley's collection of military sci-fi, *Future Artifacts* (Apex Books), takes us to a very different place. No one does future war like Hurley, and her women warriors bed themselves into your soul.

Many of the year's best books grapple with our stewardship of the planet. Ray Nayler's *The Mountain in the Sea* (MCD, pictured) features a depleted ocean that may hold a newly evolved creature with intelligence on par with ours.



Emmi Itäranta looks further ahead in *The Moonday Letters* (Titan Books), a genre-busting, edge-of-your-seat, deeply weird yet satisfying look at what lies in the post-Anthropocene era.

Christopher Priest takes a different approach to hope in his climate thriller *Expect Me Tomorrow* (Gollancz), cli-fi for all who think they are sick of it.

And *Africa Risen* (Tordotcom), a collection of short stories by African and African diaspora writers, takes it all on in a bid to withstand the tide of fear and uncertainty. At least people are writing their way out of what look like overwhelming odds. ■

Sally Adee is *New Scientist*'s sci-fi columnist

The TV column

Getting real Zac Efron's *Down to Earth* eco-documentary series set out to make sustainability sexy with a lifestyle approach to climate activism. Now, he is back with a far more serious season two, focusing on Australia, says **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on Twitter @inkerley

TV

Down to Earth With Zac Efron: Down Under

Netflix

Streaming now

Bethan also recommends...

TV

Our Planet

Netflix

A stark illustration of the fragility of our ecosystems, Our Planet *is perhaps David Attenborough's finest documentary work to date.*

Rotten

Netflix

This documentary series investigates how neoliberal capitalism has pushed the global food supply chain to breaking point, and with it our environment.

NETFLIX

Zac Efron, pictured in the new season of *Down to Earth*

BETWEEN the covid-19 pandemic and the slow boil of climate change, times have been hard of late. If, like me, you have been shocked by the extent of recent human tragedies and ecological devastation, you may now be a more solemn, sensible person than you were five years ago.

The same, it seems, is true of Zac Efron. The actor first tried out environmentalism in season one of *Down to Earth With Zac Efron*, shot in 2018 and 2019. Part eco-documentary, part-foodie travelogue, he toured the world with self-styled wellness expert Darin Olien, tackling climate change and sustainability from a wide-eyed, puppyish perspective.

The series was predicated on a simple hypothesis: to get people to change their behaviour to avoid environmental ruin, it is no good simply appealing to the better angels of their nature. Instead, you must exploit the human desire for social status. You need to make sustainability sexy.

This sounds reasonable, but the first season was scattergun and uneven. Its optimistic tone was a lifeline in a sea of "serious" climate coverage, and it showcased some interesting technologies. Yet much time was wasted on travel porn that had little to do with the health of our planet, and it allowed a slew of questionable claims about nutrition to go unchallenged. The series was a far-from-perfect advertisement for this lifestyle-led approach to climate activism.

> **"Efron got stranded in Australia during its lockdowns and fell in love with its unique biomes and species"**

But that was the Before Times. After Efron became stranded in Australia during the country's covid-19 lockdowns, he fell in love with its unique biomes and species. *Down to Earth With Zac Efron: Down Under* was the inevitable result, and I am happy to say this sophomore season is a more mature take.

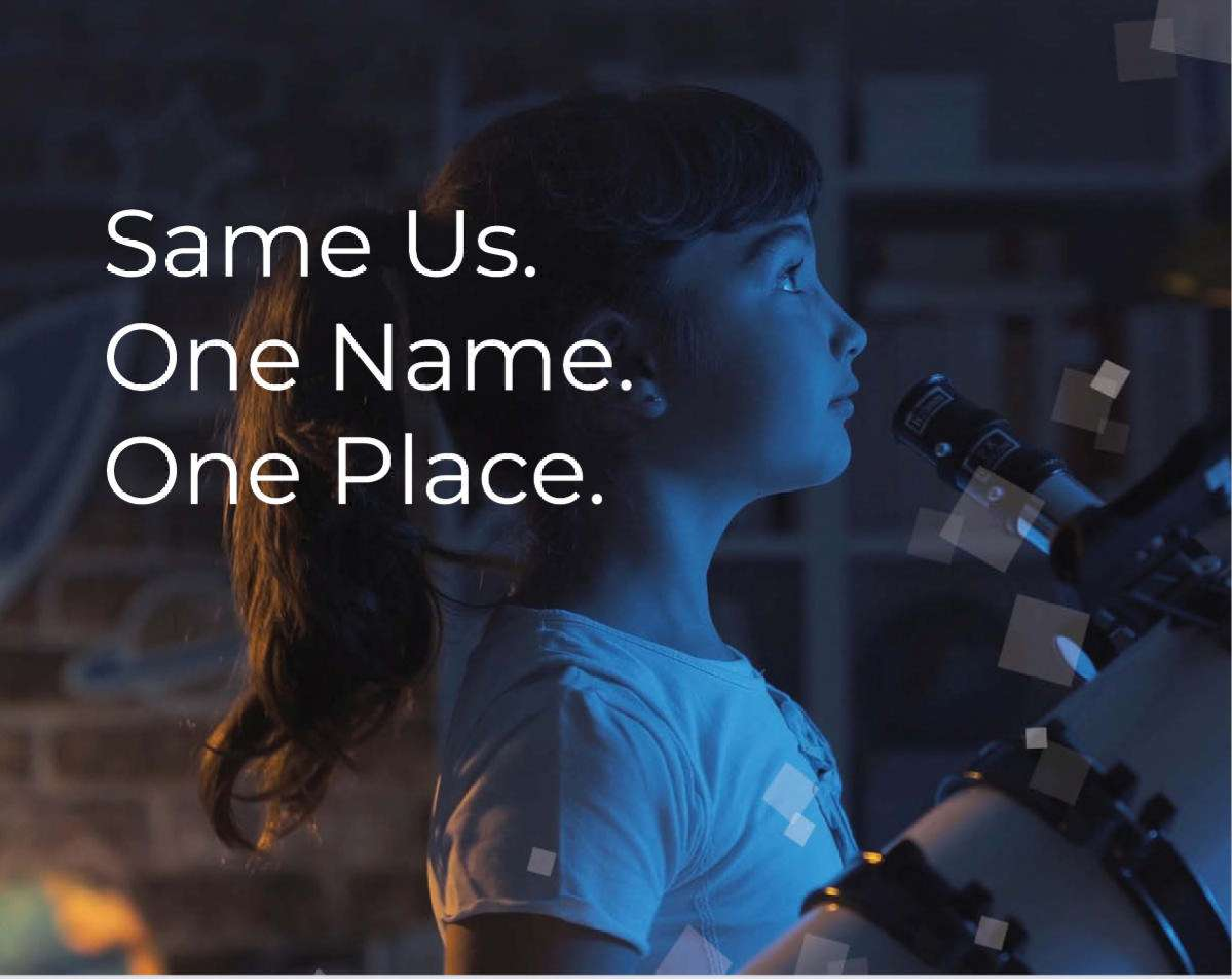
Over eight episodes, Efron and Olien explore the challenges of sustainability in Australia. One minute the pair are travelling to pristine natural sites or helping with conservation programmes, the next they are visiting zero-waste housing projects or seeding coral off the coast. In a particularly moving episode, Olien, whose home burned down in the 2018 California wildfires, meets people and animals affected by Australia's bushfires in 2019 and 2020.

Gone, mostly, are the lengthy montages of lads on tour, replaced by some important fundamentals, such as animated explainers of concepts like biodiversity loss and sea level rise.

Crucially, this season highlights how environmental crises past and present have had unequal effects. Australia's light yet fecund soil turns out to have been managed sustainably by Indigenous peoples until British colonisers introduced their own farming methods in the 18th century, leading to a rapid decline that left the country with some of the least fertile land in the world.

Even in its wiser form, the series won't charm everyone. You may feel a greater call to action at the sight of shrinking glaciers, accompanied by the dulcet tones of David Attenborough – which Efron subconsciously copies from time to time. But we aren't all the same. And as Efron points out: "That's the thing about changes like these. They start out so small... then they start to build and they catch on, then suddenly the old ways seem so outdated."

His new effort could be a step in the right direction. Any approach that makes a greener, fairer world seem not only possible, but desirable, is worthy of respect. Hell, more than that, it's sexy. ▮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Quantum flatlands

A surprising discovery in misaligned layers of graphene has opened a wild new frontier of exotic physics of two-dimensional materials, finds **Philip Ball**

IT WAS March 2018. The atmosphere at the annual meeting of the American Physical Society at the Los Angeles Convention Center was highly charged. The session had been moved to the atrium to accommodate the crowds, but people still had to cram onto the balconies to get a view of the action.

Rumours had it that Pablo Jarillo-Herrero, a physicist at the Massachusetts Institute of Technology, had something momentous to report. He and his colleagues had been experimenting with graphene, sheets of carbon just a single atom thick that are peeled from the graphite found in pencil lead. Graphene was already celebrated for its various promising electronic properties, and much more besides.

Here, Jarillo-Herrero showed that if you stacked two graphene sheets and twisted, or rotated, one relative to the other at certain "magic angles", you could make the material an insulator, where electric current barely flows, or a superconductor, where current flows with zero resistance. It was a staggering trick, and potentially hugely significant because superconductivity holds promise for applications ranging from quantum computing to nuclear fusion.

MARCUS MARRITT

Researchers have since used twisted graphene to generate all manner of exotic quantum effects, including "quasiparticles" that can manifest as magnetic vortices and otherwise exhibit bizarre electronic properties. "What's exciting about these systems is that they hold huge potential for surprise," says Amir Yacoby at Harvard University.

Even more exciting is that we have barely started on this journey. Now, by inserting more sheets of graphene or swapping in sheets of other materials to produce similar effects, we are delving deeper into the wild new physics lurking inside two-dimensional materials.

Studies of these skewed, layered substances offer a new way to investigate the fundamental nature of materials, and more specifically how the arrangement of atoms affects their properties. Whether a material conducts electric current or not stems from how the electrons in its atoms are distributed around their nuclei. Broadly speaking, the distributions of electrons on neighbouring atoms overlap to form extended "bands" throughout the material. In a conducting material, the electrons with the most energy occupy a band that has room for lots of other electrons, so they are mobile: apply a voltage and they can flow as an electric current between the electrodes. In an insulator, the highest energy band is, like the other bands at lower energies, totally filled with electrons. So the electrons, like a crowd in a packed room, have no freedom to move around.

In graphene, the carbon atoms are linked into a honeycomb-like hexagonal lattice and there is a band where electrons are free to roam throughout this, making them extraordinarily mobile – a promising quality for high-speed electronics. In fact, in pristine graphene, where there are no imperfections in the honeycomb lattice arrangement, the electrons theoretically move at the speed of light, as if they have no mass at all.

But if you take two layers of graphene and twist one of them with respect to the other, you can change the way electrons move. The two hexagonal grids move in and out of alignment as you cross the lattice, creating a kind of "superlattice" that repeats on a much larger scale. The same effect has been popular in "moire" textiles, where a pattern larger than the cloth mesh emerges from the play of light on the skewed layers of fabric. For electrons in graphene, their behaviour is no longer just influenced by the carbon atom lattice, but also by the moire lattice, which affects how easily they move between layers. The result is that conducting electrons in this twisted bilayer graphene can slow down drastically, changing their behaviour.

"When electrons have lots of kinetic energy, when they move very fast, they barely have time to interact," says Jarillo-Herrero. But this changes as they slow down in twisted bilayer graphene, he adds. The strong interactions mean that the electron motions become very sensitive to, and dependent on, one another. In technical terms, they become highly correlated – and here is where things start to get interesting, because correlated electrons are capable of otherwise impossible feats.

Take superconductivity. In conventional superconductors, the interactions between electrons result in them teaming up into "Cooper pairs". The laws of quantum mechanics restricting the number of electrons that can share the same properties – energy, position and so on – don't apply to these Cooper pairs. Thus they can gather en masse and race around, unimpeded by the lattice atoms, with no resistance.

In fact, a Cooper pair is an example of a quasiparticle: a collective state of many electrons that acts as if it is a new type of particle.

So if you're looking for funky electronic properties, you want your electrons to be

›

correlated. And if you want strong correlations, flat materials are your best bet. In three dimensions, the electrons have more ways of moving out of one another's reach. In two dimensions, on the other hand, and particularly in sheet-like conductors such as graphene, the electrons are more likely to come together to perform their tricks.

Eva Andrei at Rutgers University in New Jersey and her colleagues had already glimpsed magic-angle effects when they saw that odd things happened to the energy levels of electrons in samples where one graphene sheet lay atop another. The effect was particularly pronounced when one layer was rotated with respect to the other by around 1 degree. As other groups reported similar phenomena, theorists began to wonder what was going on. Among them were Allan MacDonald at the University of Texas in Austin and his colleague Rafi Bistritzer, now at Tel Aviv University in Israel. They calculated the electronic properties of bilayer graphene and found that the velocity of the electrons would fall to zero at certain twist angles. "The electrons just stop," says MacDonald. "This was a complete surprise to us."

The largest of these magic angles was around 1.16 degrees, which is still tiny and therefore demands a devilishly delicate level of control over the orientation of the microscopic graphene layers. But Jarillo-Herrero could see that this twist angle had potential as an unprecedented new "tuning knob" for electronic properties, so he decided to give it a shot.

In 2016, his team found the first evidence in twisted bilayer graphene of electron bands with very small kinetic energies, equivalent to the low velocities MacDonald and Bistritzer had predicted. Pressing on, the researchers searched for a type of non-conducting state called a Mott insulator that they thought might arise from strongly correlated electrons.

Sure enough, in 2018, Jarillo-Herrero's team observed this behaviour too – but also something more intriguing. If the researchers altered the applied voltage to fine-tune how many electrons were available to carry a current, they could produce a superconductor. As with all superconducting materials, this behaviour only emerged at very low temperatures – below 1.7 kelvin, which is less than 2 degrees from absolute zero. No one had predicted this, says Jarillo-Herrero.

Naturally, researchers quickly flocked to study the exotic electronic effects produced by magic-angle graphene. They were energised not only by the prospect of discovering new fundamental physics, but also because superconductors are in demand. They can be used in quantum bits in quantum computers, which exploit the strange laws of quantum physics to speed up certain calculations, as well as in technologies that use strong magnetic fields, such as MRI machines and nuclear fusion reactors.

One way to produce a magnetic field is by running a current through a coiled wire. Ramp up the currents using superconducting wires and much larger magnetic fields are possible. But the need to cryogenically cool superconducting wires makes them hard to work with. Which explains why some people were intrigued by the possibility that the superconducting behaviour in magic-angle graphene might offer a way in to finally understanding why certain copper-based compounds called layered cuprates can superconduct at comparatively balmy temperatures as high as 135K (-138°C). First reported nearly 40 years ago, the behaviour has foxed the field ever since.

"Magic-angle graphene has proved fertile ground for the discovery of quasiparticles"

MONTY RAKUSEN/CULTURA CREATIVE RF/ALAMY

With a little twist, graphene samples can produce strange physics

"We do not know yet if understanding magic-angle graphene will help us understand the origin of superconductivity in cuprates," says Jarillo-Herrero. Both the cuprates and the magic-angle graphene are layered materials and share other characteristics, he says, but they have many differences too. "My intuition is that it will [help], but it's too early to tell."

In any case, there are plenty of intriguing phenomena to discover with magic-angle graphene. For example, it can be made ferromagnetic, like iron. Ferromagnetism results from a quantum property of electrons called spin. In ferromagnetic materials, all the electrons' spins align. In 2019, by manipulating the electron bands of magic-angle graphene, David Goldhaber Gordon at the Stanford Institute for Materials and Energy Sciences in California and his colleagues were able to observe ferromagnetic properties in graphene for the first time. A controllable ferromagnet that can be switched on and off might be useful in a type of electronic technology called spintronics, where information is encoded in the spin of electrons rather than in pulses of electrical current.

Magic-angle graphene has also proved fertile ground for the discovery of new and exotic quasiparticles, including those that can have fractional charges. The charge of an electron is a fundamental unit – no free particle can have any smaller charge than this. But electrons can behave as if they have a fractional charge in a phenomenon called the fractional quantum Hall effect. While such fractionally charged quasiparticles generally behave as though they are isolated from one another, in magic-angle graphene they can line up into their own quasiparticle lattice, known as a fractional Chern insulator.

More than just a scientific curiosity, these fractional quasiparticles command practical interest because they bear a striking resemblance to "anyons" – a hypothetical quasiparticle keenly sought for quantum computing.

In the standard model of particle physics, all fundamental particles fall into one of two classes: fermions, such as electrons, and bosons, like photons. Quasiparticles generally follow the same dichotomy. Cooper pairs, for

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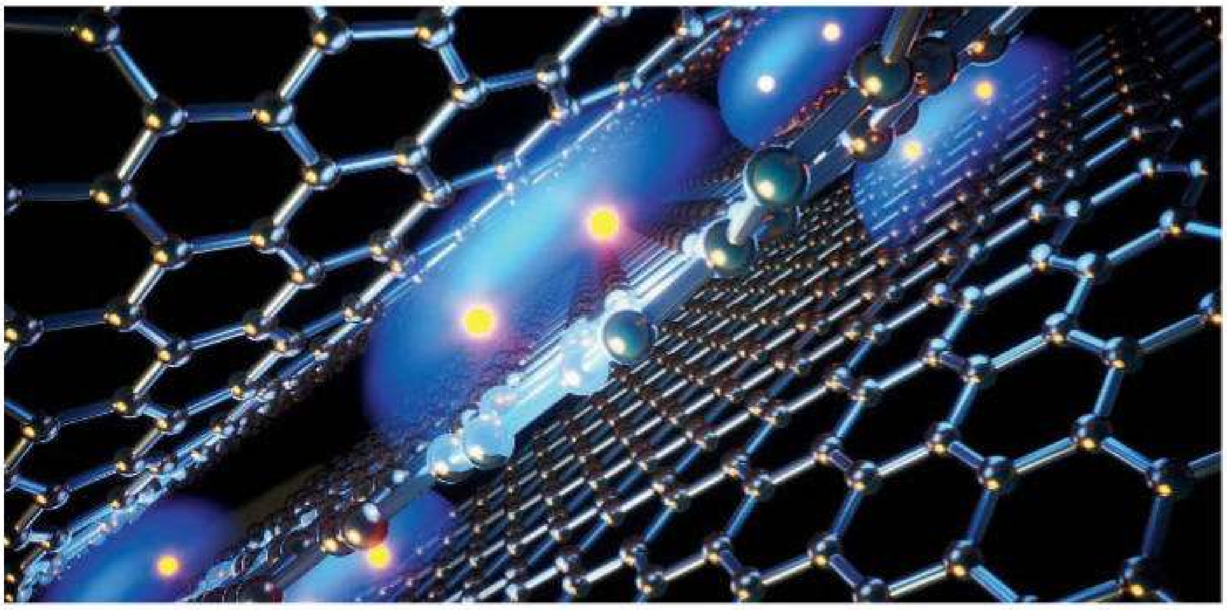

ELLA MARU STUDIO/MIT

An artist's impression of superconducting trilayer graphene

example, are bosons. But the anyon, should it exist, would be something between a boson and a fermion. One particular kind of anyon has been proposed as a quantum bit that would be resistant to the random flips in state that cause errors in quantum computation, which is currently a key obstacle to making good on the promise of quantum computers.

The discoveries keep coming. In March 2021, Ashvin Vishwanath at Harvard University and his colleagues developed a theory of superconductivity in twisted graphene based on quasiparticles called skyrmions, which manifest as magnetic vortices. Such skyrmions were reported in December by researchers at Princeton University. Then, earlier this year, Jarillo-Herrero discovered superconductivity in systems with three layers of graphene, a result replicated independently by a group led by Philip Kim at Harvard University. Jarillo-Herrero's team has since shown that the property exists even in four and five-layer systems.

"We have been able to realise pretty much all the phases of condensed-matter physics, all in a few years and by combining very simple materials," says Jarillo-Herrero. "It's quite extraordinary when you think about it."

The feat is all the more impressive when you consider what it takes to produce magic-angle graphene in the first place. Typically, Jarillo-Herrero's group takes a flake of hexagonal boron nitride (hBN) – so named because it has the same honeycomb structure as graphene – that is about 10 millionths to 30 millionths of a millimetre thick. They use this as a kind of sticky tape for stripping a single layer of graphene from graphite. Then they can pull off a second layer, rotated slightly relative to the first by manually reorienting the hBN flake, before adding the components needed to take electrical measurements.

The trouble is that reproducing these structures is excruciatingly difficult. "The physical properties of a moire system can change with minuscule changes in twist angle," says Jarillo-Herrero. Yacoby also admits that if asked to make two identical devices, "I'd be struggling to do it". In addition, he says, these systems might not be stable. "There's a lot of strain and distortion, and atoms move to find the most comfortable position."

Model behaviour

There is, however, an alternative that gets around these problems, because it doesn't rely on magic angles at all. Two sheets of different materials with slightly different spacings between the atoms can also create a moire lattice. The so-called transition-metal dichalcogenides (TMDs), such as tungsten disulphide and tungsten diselenide, also form hexagonally bonded layers and offer many permutations in which the two (or more) layers are made from different materials. For tungsten disulphide and tungsten diselenide, for instance, there is a 4 per cent mismatch in their atomic spacing, producing a moire pattern that repeats every 8 nanometres.

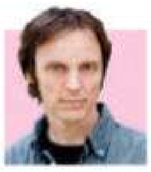
Kin Fai Mak at Cornell University in Ithaca, New York, says that because TMD bilayers aren't reliant on magic angles and therefore aren't sensitive to small variations in twist angle, experiments on them are much more reproducible. He and his colleague Jie Shan, also at Cornell, have teamed up with MacDonald to show that a moire system made from tungsten disulphide and tungsten diselenide can be used to explore all kinds of correlated electron behaviour by acting as a physical analogue of the most popular model used to describe them: the "Hubbard model".

Named after physicist John Hubbard, who proposed it in 1963, the Hubbard model breaks down electron energies into just two contributing factors – their kinetic energy and the energy of their interactions. It has been a popular go-to for investigating Mott insulators, superconductors – especially the cuprates – and ordered magnetic systems. Yet, for all its beguiling simplicity, it is so difficult to work with mathematically that an exact solution to the equations in the model still only exists for one-dimensional systems.

The good news is that "these moire materials are just about a perfect mapping of [the Hubbard model]," says MacDonald. By altering the voltage applied to their TMD bilayer sample, Mak and Shan could make a range of material behaviours predicted by the model, such as the transition between a ferromagnetic state and an antiferromagnetic one, where the atomic spins alternate in orientation. Instead of a complicated calculation, they could deduce what the model predicts by experiment.

MacDonald says we can't be completely confident what these moire systems will reveal. Even so, he is cautiously optimistic about the progress we can expect when it comes to understanding magic-angle graphene superconductivity. "This progress will have implications for understanding high-temperature superconductivity," he says.

We should expect some surprises. Jarillo-Herrero's initial discovery of superconductivity in these systems came completely out of the blue. And despite the progress made in the years since, he insists that "we have barely scratched the surface of the many hundreds of possible moire systems we can build, with very different constituents, geometries and complexity". These are our first steps into an uncharted landscape of possibilities. ▮


Philip Ball is a freelance science writer based in London. His latest book is *The Modern Myths*

Britain's lost rainforests

Rainforests grow in temperate regions as well as the tropics – and those that are found in England, Wales and Scotland desperately need our help, says **Guy Shrubsole**

FOR most of my life, I didn't realise that Britain has rainforests. But then, two years ago, I moved to Devon. Exploring woods in forgotten valleys and steep-sided gorges, I found places exuberant with life.

I witnessed branches dripping with mosses and trees festooned with lichens and liverworts. Even in winter, when deciduous trees lose their leaves, these woodlands were green with a verdant luminosity due to the plethora of species clinging to them. My adventures took me to places that felt like green cathedrals. Sunlight picked out the arches of tree trunks with their haloes of moss.

I was enraptured. Surely, I thought, such rich woodland belongs in the tropics, not the UK. But it is true. The British Isles harbour fragments of a globally rare habitat: temperate rainforest.

While tropical rainforests are characterised by being rainy and hot, temperate rainforests are rainy but cool. They are rarer than the tropical variety, covering just 1 per cent of the world's surface. They can't match Amazonia for scale, but these habitats nonetheless teem with species and may be important carbon sinks.

Tragically, however, the British Isles have lost most of their rainforests to deforestation. In England, Scotland and Wales, the remaining fragments total at most 130,000 hectares. But there is hope for their future. With the right action, I believe the area they cover could double within a generation – and that by helping these rainforests flourish, the UK would send a powerful message on the importance of protecting rainforests the world over.

Temperate rainforests require a lot of rain to thrive: around 1400 millimetres annually, according to a study published 30 years ago by Paul Alaback, then at the US Forest Service in Alaska. That rainfall needs to be spread across the year, in regions with year-round mild temperatures, to allow the rainforests to maintain their moisture content. These conditions are normally found in coastal areas, and temperate rainforest can be seen in the Pacific Northwest of North America and regions of Chile, Japan, Tasmania and New Zealand. Rainy weather is also common in Cornwall and Devon in the south of England, through Wales and England's Lake District to Argyll and the western Highlands of Scotland in the north. In these regions, temperate rainforest can be found.

They are quite a sight. In the rainforests I have visited, there are oaks with limbs contorted into extraordinary shapes. Holly and birch thrive too, as do rowan, hazel and ash. The conditions also allow for the flourishing of epiphytes, which are plants that grow on other plants. They include foliose lichens, such as tree lungwort (*Lobaria pulmonaria*) and various species of *Sticta*, some of which have a distinctive fishy smell. The epiphytes include some vascular plants: polypody fern and pennywort are good examples. There are also about 500 species of lichen in these temperate rainforests and more than 160 species of

ALL IMAGES BY GUY SHRUBSOLE UNLESS OTHERWISE STATED

Black Tor Beare, a rainforest on Dartmoor in south-west England

mosses and liverworts grow there, too. It is these often-ignored plants that give the rainforests their constant green aura.

Rainforest mapping

Epiphytes do more than give colour to the land, though. They may make temperate rainforests unusually potent carbon sinks. At a meeting of the American Geophysical Union last year, a team led by Hannah Connuck at Franklin & Marshall College in Pennsylvania showed that the "soils" that epiphytes form in the canopy of tropical rainforests in Costa Rica hold more carbon than ground soils. If the same holds true for the canopy soils in temperate rainforests, they may be an important part of our fight against climate change. However, investigations into this aspect of their ecology have yet to be started.

In 2016, ecologist Christopher Ellis at the Royal Botanic Garden Edinburgh, UK, calculated that across England, Scotland, Wales and the Isle of Man, the rainforest zone – the area with the right conditions to support rainforest growth – covers some 20.8 per cent of the total available land. Yet when I set out to map the surviving rainforest fragments of England, Wales and Scotland with Tim Richards at Terra Sulis Research in the UK, we found that they comprised less than 1 per cent of the land surface.

My travels haven't taken me to the rainforests of Northern Ireland, but research indicates that rainforest cover there is also patchy. Clearly, the UK has lost much of its rainforest. Most of that loss took place long ago, as a result of land clearance for agriculture from the Bronze Age to medieval times. But some rainforests were cut down in the 20th century to make way for conifer plantations. Farm subsidies, many paid for by the taxpayer, have prevented the rainforests from regenerating.

Since the second world war, agricultural subsidies in the UK have been geared towards maximising the production of food to the detriment of nature. Then, after the UK joined the European Common Agricultural Policy in the 1970s, payments to livestock farmers were made per animal, which led to huge increases in the number of sheep and cattle in upland areas. Moves to cut back on these soaring livestock populations through environmental stewardship payments in recent decades haven't yet undone the damage. There are more than twice as many sheep in the Lake District today than in the 1950s, for example.

Such high grazing densities have stopped British rainforests from returning, even in areas where the climate is perfect for them to thrive. Sheep, in particular, nibble vegetation down to a tight sward and feed on the fresh shoots of young saplings. As a result, many of the surviving rainforests are dying out. They comprise collections of creaking ›

A photographic guide to the British rainforest

OSMUNDA REGALIS

Royal fern

The crowning glory of the rainforest ferns that grow in the UK, and one of the largest ferns in Europe. Its fronds can grow up to 3 metres tall.

KEITH BURDETT/ALAMY

POLYPODIUM VULGARE

Polypody fern

One of the most distinctive species found in British rainforests. It creeps along branches, sending out horizontal roots called rhizomes.

LOBARIA PULMONARIA

Tree lungwort

The tree lungwort gets its name from medieval herbalists, who prescribed it as a cure for pulmonary diseases as its surface resembles lung tissue.

LOBARIA VIRENS

This lichen is recognisable for its startlingly green colour and its satin skin. It grows to around 10 centimetres in diameter and has red fruiting discs.

STICTA SYLVATICA

A lichen that smells of rotting fish. It has a dark brown colour when wet. Its outline is irregular and sometimes described as fan-shaped.

veteran trees in which the process of natural regeneration has been thwarted by human mismanagement.

Even protected sites are threatened. The temperate rainforest of Johnny Wood in the Lake District, supposedly safe from harm following designation as a Site of Special Scientific Interest, was assessed last year as being in an "unfavourable – declining" condition by Natural England, a non-departmental public body that advises the UK government. The problem? Overgrazing.

Rainforests that do remain healthy, meanwhile, often lie marooned in a desert of moorland, stranded far from their nearest neighbour. This lack of ecological connectivity makes it difficult for the rare species they support to spread, leaving them vulnerable to storms, heatwaves and climate change.

But there is hope for the rainforests. These extraordinary habitats can recover, and sometimes all that is required is for people to give them a break. As the late ecologist Oliver Rackham once remarked: "In England, trees grow where people have not prevented them."

According to Natural England, Wistman's Wood on Dartmoor – probably England's most famous fragment of temperate rainforest – has doubled in size over the past century. A little-known study published in 1980 by Molly and Malcolm Spooner and Michael Proctor shows why: there was a decline in grazing pressures in the wood's locality. Likewise, at Lustleigh Cleave (a steep-sided patch of common land in Devon), a rainforest has returned by accident simply because fewer people who are entitled to graze livestock on the land have been exercising those rights.

Such examples, however, are few and far between; the result of chance circumstances. More concerted rainforest restoration efforts will require active intervention. An inspiring example of what can be achieved comes from New Zealand, where botanist Hugh Wilson has worked for 30 years to turn a 1250-hectare patch of former farmland now owned by the Maurice White Native Forest Trust into a temperate rainforest known as the Hinewai reserve. Removing grazing livestock was crucial to create a rainforest containing red beech and native tōtara podocarp trees, as well as animals including kererū pigeons, jewelled geckos and 50-centimetre-long earthworms.

Wilson talked about his experiences in a 2019 viral documentary called *Fools & Dreamers*. When he arrived, the local farmers "basically thought we were naive greenies from the city", he said. Some 30 years on, he added: "I don't think there's a single farmer who's not backing [us] now."

Back in the British Isles, decades of experiments with exclosure fencing – where livestock animals are excluded from areas of overgrazed woodland, rather than penned in – have produced dramatic results: it isn't just the trees that can rebound, but also a rich understorey of bilberries, heather and wildflowers. It may even be possible to achieve such results without fencing, using GPS-equipped livestock collars that administer a mild electric shock to animals when they wander towards a protected area.

Freed from such grazing pressures, temperate rainforests would begin to spread outwards. For a sense of how rapidly they might expand, consider Monks Wood in Cambridgeshire, England, an oak woodland that has been allowed to rewild for several decades – albeit in the drier east of the country

ANDY TROWBRIDGE/NATURE PICTURE LIBRARY/ALAMY

The jewelled gecko thrives in temperate rainforests in New Zealand

USNEA ARTICULATA
String-of-sausage lichen
This densely branched lichen has a green-grey colour. It hangs from branches in great curtains, festooning entire trees.

BAZZANIA TRILOBATA
Greater whipwort
A liverwort that can grow in great mounds in temperate rainforests. It is one of the largest species of leafy liverwort and well-suited to forest floors.

HYPOCREOPSIS RHODODENDRI
Hazel gloves
Very distinctive and rare. In British rainforests, this orange fungus grows only on old, uncoppiced hazel. Looks like a mass of gloves.

F ADAM/IMAGEBROKER/ALAMY

FICEDULA HYPOLEUCA
Pied flycatcher
This declining species of bird thrives in British temperate rainforests. It eats insects and other arthropods and often nests in oak trees.

MIRCEA COSTINA/ALAMY

CARABUS INTRICATUS
Blue ground beetle
This large beetle is only found in a handful of temperate rainforest sites on Dartmoor and in south Wales. It emerges at night to prey on slugs.

where rainforests don't grow. Last year, a team led by Richard Broughton at the UK Centre for Ecology & Hydrology showed that jays, squirrels and other animals have carried acorns far from their mother trees and buried them in the neighbouring field, where they have flourished in the absence of nibbling sheep. As a consequence, the oak woodland has expanded by 100 to 150 metres in a little over 20 years.

Using our maps of rainforest fragments across England, Wales and Scotland, Richards and I ran a model in which each of them was allowed to expand by this same distance. We concluded that the area of temperate rainforest in our study region would almost double. It is astonishing to me that, using Monks Wood as a rough guide, we could potentially see such a dramatic expansion within a generation.

Crucially, this could be done with minimal impact on food production. For instance, the UK government-commissioned National Food Strategy, published in 2021, calculated that England could spare 20 per cent of its least productive farmland for nature and only reduce food production in terms of calories by 3 per cent. Across the British Isles, most of the temperate rainforests are found on marginal land: steep-sided valleys and boulder-strewn hillsides, surrounded by bracken that is unpalatable to livestock. And with increasing numbers of people reducing their meat consumption, out of concerns for their health and environmental impacts, even more land could be freed up for nature.

Nor is this just a distant dream. Work is already underway by some pioneering landowners and farmers to restore rainforests in England and Scotland. Conservation charities like the Woodland Trust, National Trust and Royal Society for the Protection of Birds are working to reconstruct temperate rainforests damaged by modern forestry plantations, from Ausewell Wood in Devon to Glencripesdale in Highland, Scotland. Estates like Cabilla in Cornwall are reconfiguring their business model around rainforest restoration, combining regenerative farming with income from eco-tourism.

> "We could almost double the area of temperate rainforest in Britain within a generation"

But to see large-scale rainforest restoration, political intervention is needed. That is why, over the past 18 months, I have been leading a campaign called Lost Rainforests of Britain to lobby the UK government on rainforest protection and restoration. For instance, nearly three-quarters of England's rainforests are unprotected: they desperately need help.

The recent political turmoil in the UK has generated uncertainty about the future of Environmental Land Management schemes (ELMs). This is the UK government's planned system of farm payments in England post-Brexit that was to have paid farmers and landowners to manage land in a way beneficial to the environment and wildlife. The UK government needs to get ELMs back on track, so that the temperate rainforests in England can get funding under ambitious Landscape Recovery projects.

Most importantly, all of the governments in the UK need to draw up rainforest strategies to tackle the many threats facing these special places, from overgrazing to invasive plants – particularly rhododendron, which spreads quickly and shades out other species with its evergreen leaves.

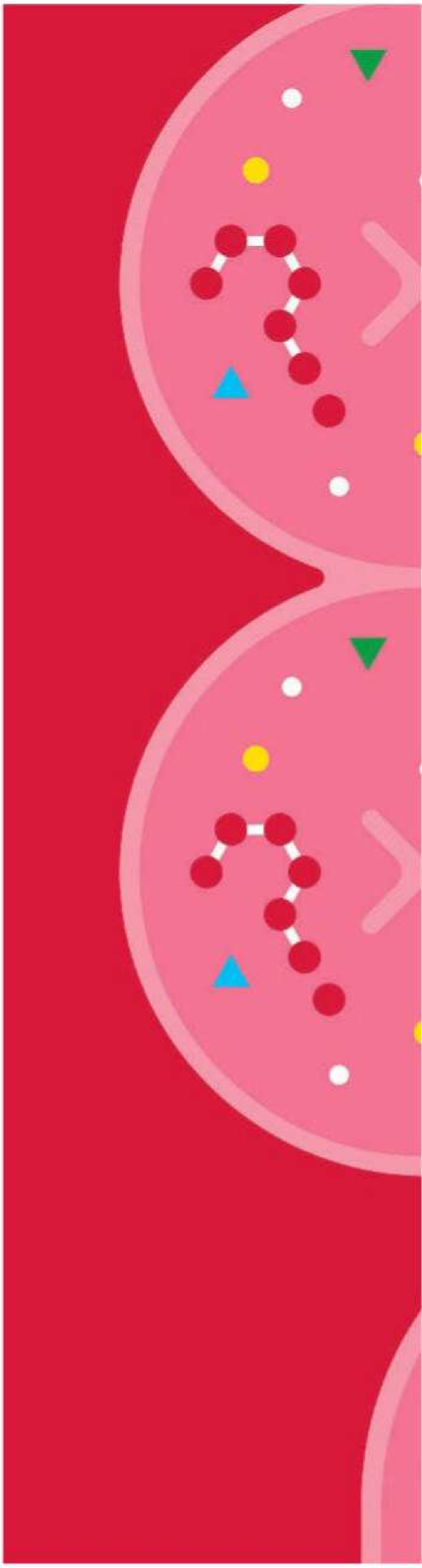
Projects to restore the lost rainforests across the UK could galvanise landowners and the wider public into repairing denuded landscapes and damaged carbon sinks. They could also add to growing global momentum to protect and restore all rainforests, both temperate and tropical. The victory of Luiz Inácio Lula da Silva over Jair Bolsonaro in the recent Brazilian presidential elections has electrified environmentalists, giving fresh hope for the Amazon rainforest: under Lula's last administration earlier this century, Amazonian deforestation fell by 80 per cent.

The governments in the UK ought to capitalise on this moment, not only by pledging more money to help lower-income countries respond to the challenges of climate change, but also through a bold ambition to bring back the lost rainforests on their own shores. ■

Guy Shrubsole is an environmental campaigner and author. His latest book is *The Lost Rainforests of Britain*

Gut reactions

Forget probiotic yogurts and prebiotic pills – postbiotics promise to boost your microbiome like never before. But do they work, asks **Jessica Bond**



IT IS 9.30am and you are feeling a bit off. You have just finished a round of antibiotics and know your gut microbes have taken a hit. You pop a pill and head out, safe in the knowledge that while the microscopic communities in your intestines may take a while to regroup, the health benefits they confer will be back up to speed much sooner. Welcome to the world of postbiotics.

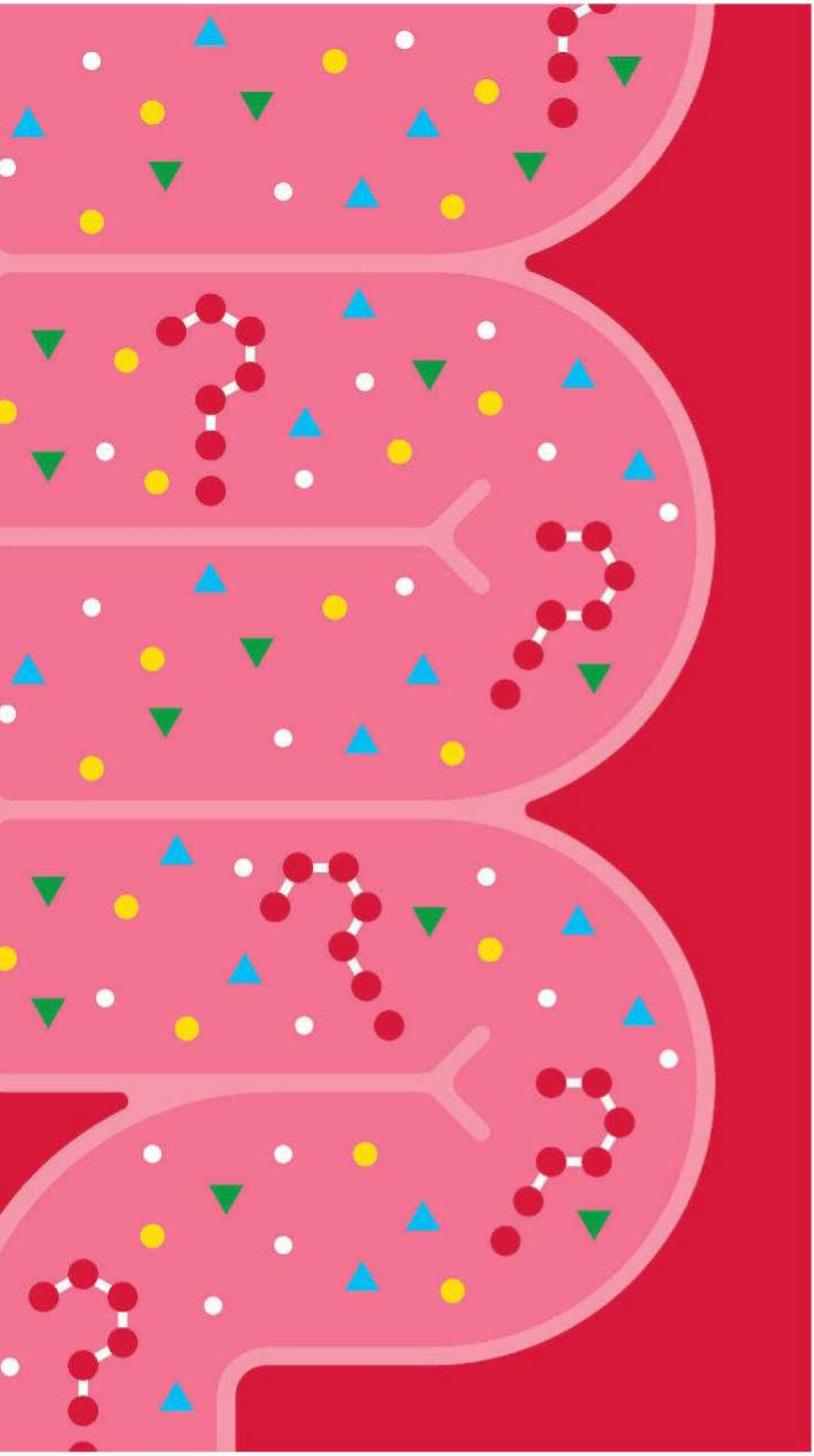
As evidence piles up about the importance of our microbiome to our health, so too has the desire to boost it. First came probiotics, the live bacteria you need in your gut. Then there were prebiotics, or the foods these microbes need to thrive. Now, there is a new kid on the block: postbiotics, a catch-all term to describe dead bacteria and the products excreted by live microbes.

It turns out that postbiotics do a lot of the heavy lifting when it comes to the relationship between your gut microbiome – made up of bacteria, fungi and viruses – and good health. And by cutting out the go-between, you can sidestep many of the problems that come with trying to optimise gut health by other means. "There's excitement building around postbiotics," says Colin Hill, a microbiologist at University College Cork in Ireland. "It feels like we're at a nexus where this field is potentially going to explode." Certainly, lifestyle magazines and health food shops are extolling their benefits for everything from better skin and stronger muscles to stopping hot flushes and preventing diarrhoea. But what exactly are postbiotics, how do they work and are they really the easy path to perfect gut health we have all been waiting for?

Let's start with the 100 trillion bacteria, fungi and viruses that live in and on our bodies, mainly in the gut. We know this microbiome is linked to good physical and mental health. The relationship is mutually beneficial: in exchange for providing food and board, beneficial gut microbes support our immune system, protect us from bad bacteria and help us digest food. They also affect our energy levels, alter the way we store fat and change how we respond to hormones that make us feel hungry or full, says Harriët Schellekens, also at University College Cork. Recent evidence suggests that the microbiome also affects the brain, has an influence on our behaviour and even plays a role in ageing.

Our gut microbes, though, are sensitive souls. The balance of what is living in our intestines and the good they do is affected by our diet, our age and where we live, and it can be knocked off the rails by stress and drugs such as antibiotics or chemotherapy. This is where pre and probiotics come in. For several decades now, they have been marketed as a way to repopulate your gut to maintain microbial diversity and keep it healthy. Your microbiome is big business: in 2021, the global probiotics industry was estimated to be worth almost $60 billion, and growing.

Pre and probiotics have a lot going for them. There is evidence that taking probiotic supplements can help reduce bouts of diarrhoea after a course of antibiotics, help manage digestive issues such as irritable bowel syndrome and have a modest effect on the risk of getting a cold and its length. According to the Alliance for Education on Probiotic Products, which publishes an independent review called the Probiotics Guide (a list of supplements available in the US and Canada and their dosage backed up by data in humans), there is also some evidence that probiotic supplements can help with traveller's diarrhoea, constipation, *Helicobacter pylori* and *Clostridium difficile* infections, thrush and



PÂTÉ

mastitis. Use of prebiotic supplements, which are, in essence, food for beneficial gut bacteria, has less evidence behind it, but studies suggest that they may regulate our desire to eat by making us feel fuller and improve calcium absorption, which is good for bone health.

Even so, attempts to boost our microbiome with pre and probiotics aren't without issues. For a start, we don't yet know enough about what gut microbes feed on, while studies have shown that live microbes in supplements don't always survive the journey through our digestive tract. Then there are problems that come from dealing with live microbes. They must be carefully stored, as many are sensitive to heat or humidity, and dosing isn't an exact science because it is hard to know how many will be alive at any one time. While live probiotic bacteria causing illness is rare, this does occur and can be serious for people with weakened immune systems.

Enter postbiotics. While their exact definition is debated, they are generally considered to be one of three things: dead microbes, which are more useful than you might imagine; fragments produced when microbes break down; and chemicals such as enzymes, vitamins, polysaccharides and short-chain fatty acids that microbes have secreted. Each exerts its own effect, sometimes by triggering interactions with other species or, more often, by interacting directly with our body via the gut.

If the gut microbiome is like a natural pharmacy, postbiotics are the medicines it dispenses. "Microbes are crucial for your health only because of the amazing things that they produce, which are these postbiotics," says Tim Spector at King's College London.

A natural pharmacy

So far, much of the work identifying and exploring the potential of postbiotics has been done by experimenting on cells and animals, but there are some promising findings in people too. Take short-chain fatty acids, for instance. These are metabolites produced when microbes in our large intestine consume indigestible fibre, like inulin found in foods such as leeks, bananas and asparagus.

One short-chain fatty acid called butyrate seems to be particularly helpful. This interacts with immune cells to help maintain our immune system's fine balance between tolerating the good bacteria in our gut and reacting to any bad bacteria that try to muscle in. A lack of butyrate has been implicated in food allergies and recent work has suggested that this metabolite plays a ›

> **“Butyrate plays a role in food tolerance. There’s one problem – it smells like a fart”**

role in developing food tolerances in the first years of life. It also keeps the gut wall strong, reducing inflammation that contributes to obesity and bowel diseases. Clinical trials suggest that butyrate can be a useful supplementary therapy for ulcerative colitis, and enemas that contain it can treat diversion colitis, which can occur when part of the intestine is starved of nutrients following surgery.

There is just one problem. “Butyrate smells like a fart,” says Wojciech Feleszko, a paediatric immunologist at the Medical University of Warsaw, Poland, and author of a recent review of potential postbiotics. Taking butyrate directly therefore is a challenge. But researchers at the University of Chicago have encapsulated the substance in spherical containers called micelles to treat food allergies, demonstrating promising results in mice. They are hopeful that their tiny, odourless capsules could treat or even prevent these allergies in people.

Another example of a promising postbiotic is equol, produced when certain gut bacteria break down a compound in soya. It resembles the chemical structure of the female sex hormone oestrogen and some studies have proposed a link between the ability to produce it in the gut and a lower risk of breast cancer. A small trial also found it could reduce the severity of menopausal hot flushes.

The ability of some postbiotics to modulate the immune system – by ramping it up or down – also means they have been investigated as a promising adjunct to cancer therapies. For instance, studies have shown that certain postbiotics can help reduce side effects of immunotherapies, which boost the immune system to fight cancer, while others seem able to suppress tumours. Early work with different types of cancer cells has shown that the waste products secreted by *Lactobacillus* bacteria can trigger the death of cancer cells or reduce their ability to invade other tissues.

But research into postbiotics hasn’t only focused on how it can be used to help treat specific clinical conditions, there is now an increasing volume of work on its potential as a consumer product. Postbiotic supplements can already be found in health food shops and online throughout the UK and US. The question is, to what extent do they work?

Better ageing

Take urolithin A (UA), a metabolite produced when our gut microbes feed on things like walnuts, pomegranates and strawberries. This substance is thought to help maintain functioning mitochondria, which power our cells, something that declines with advancing years and which is implicated in various problems associated with ageing. Not everyone has the right mix of gut flora to produce this metabolite from food, which led to interest in developing an oral supplement. In clinical trials, a Swiss company called Amazentis has shown that taking UA supplements can improve mitochondrial health in older people, increase leg strength and alleviate the pain of osteoarthritis. These findings led to the launch of Mitopure, the first UA supplement, in 2020. The promise of mitochondrial wellness doesn’t come cheap, though – two months’ worth of their capsules costs $200.

Meanwhile, other researchers are focusing on the beneficial effects of using dead bacteria to supplement gut health. As counter-intuitive as it may sound, bacteria don’t have to be alive to be helpful. For instance, *Akkermansia muciniphila* is a microbe that feeds off the gut’s mucous lining, and regularly turns up in the microbiomes of slim, young people with no known health conditions. Conversely, lower levels are found in people with obesity, type 2 diabetes and irritable bowel diseases. Research showed that supplementing mice with *A. muciniphila* protected them from becoming obese.

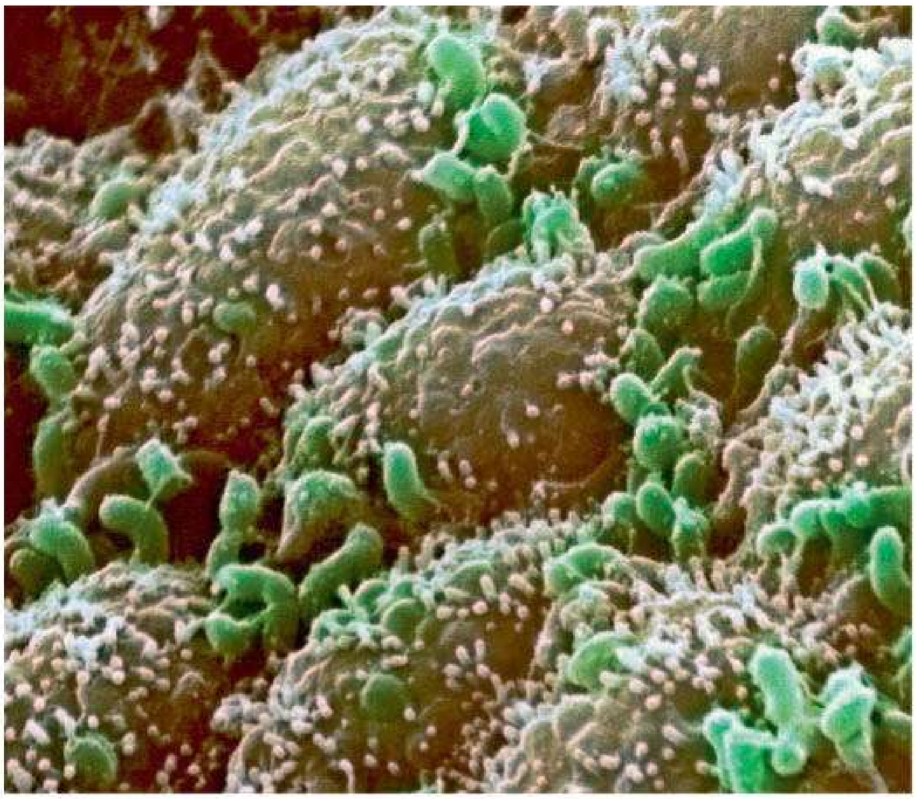
What does your poo say about you?

Recently, a host of consumer companies have sprung up offering to sequence the genetic material in a poo sample to give you an overview of your gut health. This may be a fun way to satisfy your curiosity about what microbes call you home, but the science hasn’t advanced far enough for these tests to give meaningful information about health or disease, says the charity Guts UK.

We are at the stage where genetic sequencing of human DNA was 30 years ago, says Kevin Honaker, CEO of Chicago-based tech firm BiomeSense. We might be able to access the microbiome’s genetic profiles, but we can’t reliably interpret them as we don’t yet understand how it all fits together, he says.

For this, we need a big data approach, and it is here that other forms of consumer testing could be of use. Take the precision nutrition Zoe app that Tim Spector at King’s College London and his team have developed. “It’s a consumer product, but everyone signs up for research,” says Spector. “We’ve now got over 30,000 people’s data and we’re linking it to their nutrition. We’re finding all these new associations, both between the drugs they’re taking and their microbes.” The dataset is increasing so quickly, they are on track to have analaysed a million microbiomes within a few years.

Eventually, you might find yourself getting information about your gut health from a high-tech toilet. Early prototypes include a “smart toilet”, developed by start-up Coprata, which uses sensors and artificial intelligence to analyse your waste. It is based on the work of the Smart Toilet Lab at Duke University in North Carolina. BiomeSense also has a technology called GutLab, which consists of a rectangular unit into which people drop their used toilet paper. Eventually it hopes that it could give consumers a real-time read out of what is going on inside their guts. For now though, its research is focused on building datasets big enough to answer the fundamental questions about the microbiome: what microbes are there, what they are up to and what impact they have on our health.



BIOMEDICAL IMAGING UNIT, SOUTHAMPTON GENERAL HOSPITAL/SCIENCE PHOTO LIBRARY

Bacteria on the surface of the small intestine

Since *A. muciniphila* had never been investigated as a postbiotic supplement in people, Patrice Cani at the Catholic University of Louvain in Belgium and his colleagues conducted a clinical trial involving 32 overweight or obese volunteers. It showed that regardless of whether the bacteria were dead or alive, they led to improved insulin sensitivity, which can reduce the risk of type 2 diabetes, lower blood cholesterol and lower body weight compared with people who took a placebo. The team was even able to identify a protein on the surface of this bacterium that they think is responsible. Two researchers involved in the trial have since created the Akkermansia Company, which last month launched a food supplement containing deactivated *A. muciniphila*, as a means to help people manage weight and reduce their risk of cardiovascular disease and type 2 diabetes.

Working with dead bacteria or waste products from microbes offers several practical advantages. Unlike probiotics, you don't have to store them under perfect conditions to keep the bacteria alive and you don't have to worry about them growing out of control in the gut. This means you can be more certain of the dose, and there are fewer safety concerns.

However, Gregor Reid, an emeritus professor at Western University in Ontario, Canada, says that we need more evidence that postbiotics will make it intact to our guts.

A lack of high-quality trials also plagues the industry. In 2019, an international group of scientists agreed that for a product to be designated as a postbiotic, it must be proven to confer a health benefit in a controlled, high-quality trial. Not many supplements currently on the market have the human data to warrant this label, says Reid. "The consumer needs to know what it is that they are buying and what they can expect it to do. Unfortunately, the commercial side is so fast at catching on to new terminologies, that it gets ahead of the science and the result can be total nonsense."

What's more, supplements are only going to work if there is something to fix, says Schellekens. For example, about 25 per cent of women in Western countries have the right set of microbes to turn soya into equol, the metabolite that improves oestrogen-linked problems. A supplement only makes sense for the other 75 per cent.

For now, diet may be the best route to postbiotic benefits. The usual advice stands: eat diversely with plenty of plant-based fare and steer clear of ultra-processed foods. It is accepted wisdom that eating fermented foods, such as yogurt, kimchi, miso, kombucha and kefir, is good for us as these contain live bacteria that can make postbiotics. But even this is more common sense than evidence-based, says Hill. "Certainly, fermented foods seem to be a part of most healthy diets around the world, but we don't have direct evidence that this is because they have bacteria in them, alive or dead. This is something we are trying to generate the evidence on."

He says that part of the problem is that there are no reliable biomarkers for gut health, unlike for our heart or liver (See "What does your poo say about you", page 48). "If we had numerical readouts for the state of your microbiome, we could then see whether we're improving it with every action you take, but we're not there yet," says Hill.

Despite the hurdles, Schellekens is hopeful that the postbiotic revolution will lead to new drugs. "We have a natural factory of microbes that can make loads of things that are beneficial for us. It's just a huge untapped resource," she says. Spector's money is on postbiotics that could support cancer immunotherapy. "You've got this whole pharmacy waiting inside your gut," he says. Now the challenge is to learn how to harness it. ▮

"If the gut microbiome is a natural pharmacy, postbiotics are the medicines it dispenses"

The postbiotic urolithin A (UA) is produced when gut microbes feed on pomegranates (above); Mitopure is the world's first UA supplement (left)

TOP: SHUTTERSTOCK/YELLOW CAT; LOWER: TIMELINE NUTRITION

Jessica Bond is a science journalist based in London

HMR

DRUG DEVELOPMENT OPPORTUNITIES AT TRIO MEDICINES LTD

Trio Medicines Ltd (Trio) is a small pharmaceutical company founded in 2007, wholly owned by Hammersmith Medicines Research Ltd (HMR), a Contract Research Organisation (CRO) based in NW London. Currently we have four projects at various stages of development. See www.triomedicines.com

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- Designing pre-clinical/non-clinical and clinical studies
- Liaising with CROs and Contract Development and Manufacturing Organisations (CDMOs)
- Preparing regulatory documents and liaising with regulatory authorities
- Staying informed of the current literature in the relevant disease areas

Excellent technical, writing and communication skills are essential for all three roles, as is the ability to work both independently and in a multidisciplinary team. We ask for candidates with exceptional organisation skills and attention to detail.

Here at Trio, we are committed to developing science-based medicines to treat diseases with an unmet medical need. We welcome applications from scientifically driven and enthusiastic individuals who share our values

Please specify which of the three roles you are applying for and e-mail a covering letter and your CV to:**Trio@triomedicines.com**

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Further information about this position and how to apply is available on the Gresham website at: www.gresham.ac.uk/professor-astronomy

Or contact the Academic Programme Manager, Mariam Ismail (m.ismail@gresham.ac.uk)

The closing date is 9:30 am **9 January 2023.**
Interviews will be held in London on **28 February 2023.**

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Email: liam.watson@imperial.ac.uk

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The back pages

Puzzles
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***Almost* the last word**
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On singing out loud and storing energy from sweat p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Stargazing at home

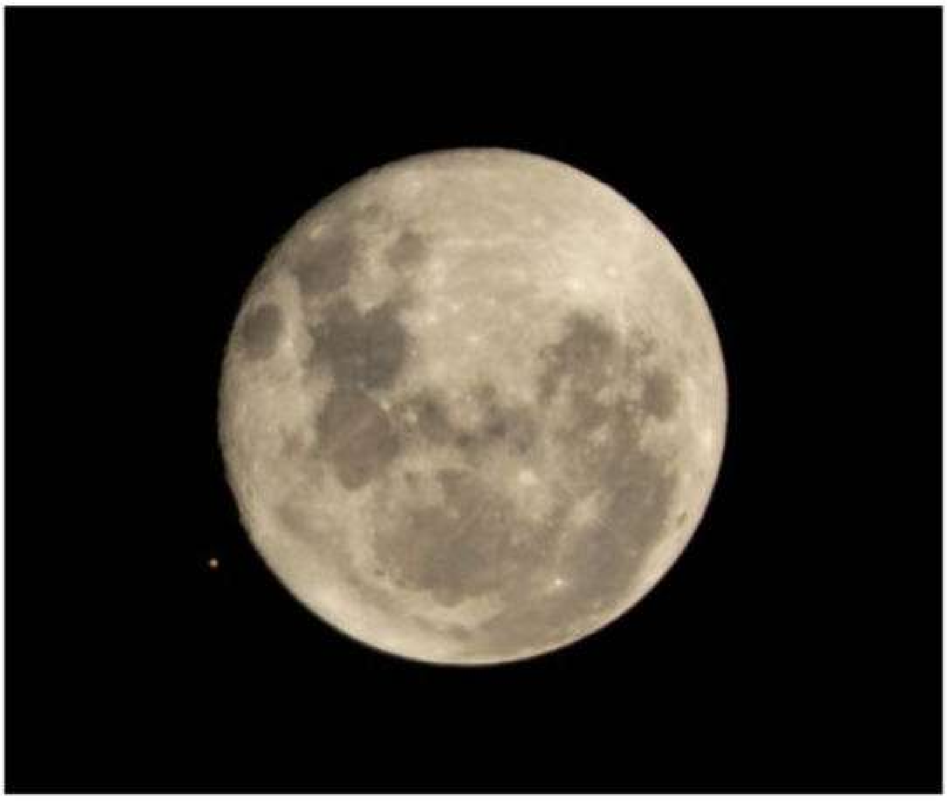
A Martian vanishing act

On 8 December, a rare lunar occultation of Mars will be visible from parts of the world. **Abigail Beall** explains how to spot it

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need

Binoculars or a telescope (optional)
Stargazing software such as Stellarium (optional)



TACIO PHILIP SANSONOVSKI/ALAMY

EARLIER this year, I wrote about how to watch the faint planet Uranus disappear behind the moon, in a rare event known as a lunar occultation. Now, it is time for another lunar occultation, but this time of Mars (pictured, to the left of the moon).

Uranus, which is 2.6 billion kilometres away from Earth at the closest point in its orbit, is difficult to see with the naked eye. Mars, although much smaller, is far easier to spot. As our nearest planetary neighbour, Mars can get as close as 56 million kilometres away, at which point it is the third brightest planet in the night sky after Venus and Jupiter. So on 8 December, when Mars's orbit will make it look as if it is disappearing behind the moon, it will be a spectacular sight – for those who can view it.

Occultations like this are only visible from certain points on Earth's surface, since the moon is so close it appears at a slightly different position in the sky depending on where we view it from. This phenomenon, known as parallax, is easy to demonstrate. Hold your hand out with your thumb up and close one eye. Then open that eye and close the other and see how your thumb appears to move. This is because you are viewing it from a slightly different point – your other eye. Parallax is useful for measuring distances to nearby astronomical objects, but it also means the moon will only appear to be in front of Mars from some points on Earth.

Those of us who happen to live in a place where our view of the moon lines up with Mars, and where it is dark at the time Mars passes the moon's orbit, will have a chance to see this month's occultation. On this occasion, that happens to be in western parts of Europe, most of North America and some parts of north Africa.

This occultation is particularly rare because it falls on the same day Mars will be at opposition, meaning it is exactly on the other side of Earth from the sun. Planets at opposition appear brighter to us because their faces are fully lit by the sun, and they are visible for most of the night. Mars will next be at opposition in January 2025.

To watch this event, you will need to be prepared. Mars will appear to pass behind the moon and then reappear some time later. It will take about 36 seconds from when it looks as if Mars is touching the moon for it to totally vanish. It will be gone for about an hour, then take another few seconds to reappear fully. If you have binoculars or a telescope, these will give a clearer picture of the disappearing act, but it will also be visible with the naked eye.

The exact time the occultation will be visible for you depends on where you are. In the UK, it will begin just before 5am and end just after 6am. But to get a precise time, use software like Stellarium to plan your viewing, as even within the UK the timings will vary by a few minutes. ▮

These articles are posted each week at newscientist.com/maker

Stargazing at home appears every four weeks. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing

Next week

Science of gardening

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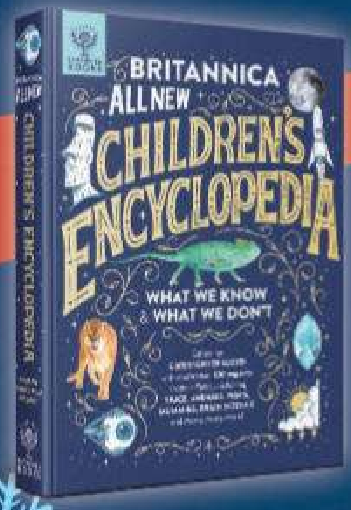
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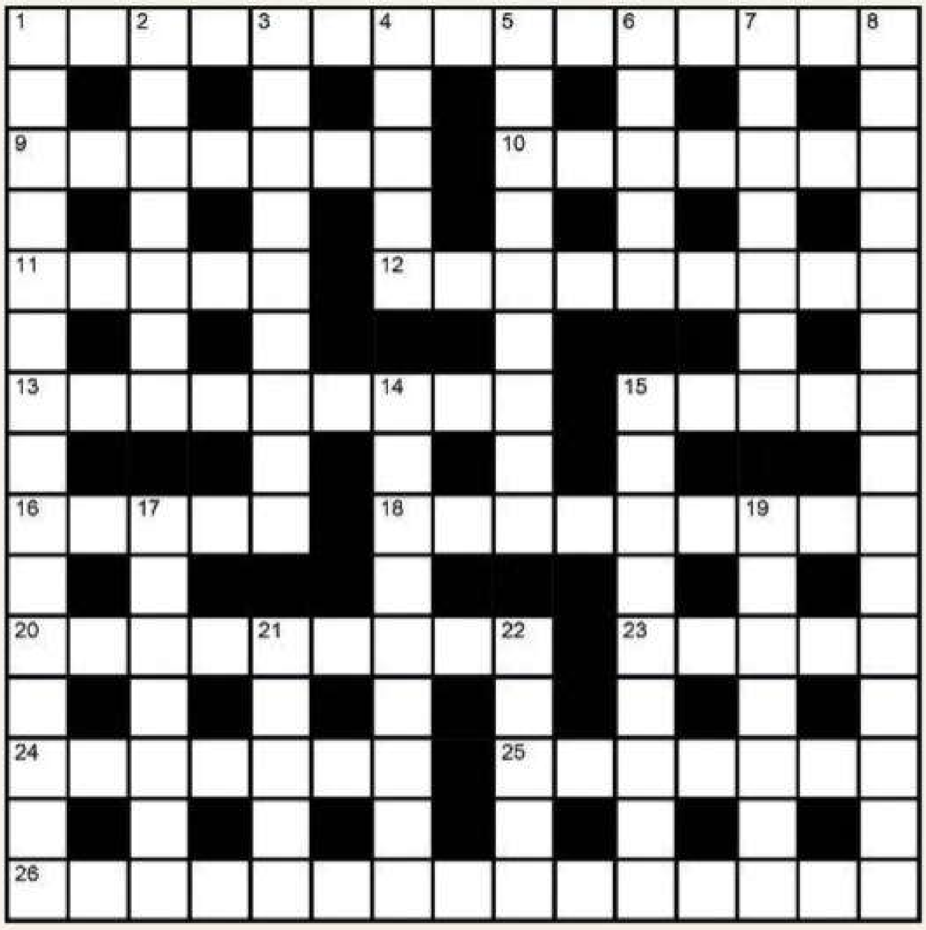
Quick crossword #122 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 1985 sci-fi film directed by Robert Zemeckis (4,2,3,6)
9 Sequoia (7)
10 Tin-glazed pottery (7)
11 Bristles, perhaps (5)
12 Root parasite in the genus *Pedicularis* (9)
13 Srinivasa ___, Indian mathematician (9)
15 *Lacticaseibacillus* ___, bacteria used in dairy fermentation (5)
16 Plant organs that provide anchorage and nutriment (5)
18 Blood suffusion, bruise (9)
20 Psychoactive substance (9)
23 Clamps (5)
24 Device for establishing a line of sight (7)
25 Jupiter probe launched in 1989 (7)
26 Decoherence proposition in quantum mechanics (2-6,7)

DOWN

1 19th-century German mathematician (8,7)
2 Cd (7)
3 1000s (9)
4 Relating to the movements of the seas (5)
5 Outflow (9)
6 Waste water (5)
7 Nonvascular plant of wet habitats, genus *Physcomitrium* (3,4)
8 Atmospheric disturbance characterised by lightning flashes (10,5)
14 First American to orbit Earth (4,5)
15 English East Midlands town, important in the industrial revolution (9)
17 Largest bird in the world (7)
19 Relating to a sucker or orifice (7)
21 Antelope of southern Africa (5)
22 Period of darkness that follows day (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #180

set by Bethan Ackerley

1 What is the largest order of mammals?

2 Who coined the term "gene" in 1909?

3 In astronomy, the boundary at which the solar wind from the sun dramatically slows down to below the speed of sound is known as what?

4 The three types of charged lepton are electrons, taus and what?

5 Nephology is the study of what?

Answers on page 55

Puzzle

set by Howard Williams

#196 Champion trainer

Three top racehorse trainers, Kate Winsalot, Britney Spurs and Harry Trotter, were invited to compete in the prestigious Champion Trainers Stakes.

Each had to enter three horses in the race, with points being awarded to the trainer according to the finishing position of their mounts. The trainer of the winning animal would be awarded 9 points, the second placed horse 8 points, and so on, down to 1 point for the trainer of the last horse. The person receiving the most points is the Champion Trainer.

The results of the race were delayed waiting for Bored Bronco, one of Harry's horses, to finally finish and also because two of Kate's runners had to have their positions determined by photograph, with her third horse finishing further back.

When the scores were calculated, it turned out that the three trainers had tied on points. Which trainer's horse came first?

Solution next week

Odds-on

If "the house always wins", how do professional gamblers make a living?

Mark Wood
Bedford, UK
The "house" bases its odds on the average of the bets placed. However, it is often the case that a large percentage of the bets have been placed by relatively unsophisticated gamblers. This can lead to situations where the average odds may be significantly different from the odds they face.

Professional gamblers keep a close watch on the situations they gamble upon and seek situations where they figure that the actual odds are in their favour when compared with the bookmakers' odds.

@jiimiettinen
via Twitter
If the house literally always won, it wouldn't be gambling. The house wins in the long run against the majority of players.

> "Professional gamblers are masters at predicting bluffs and capitalising on poor strategies used by other players"

Pat French
Telford, Shropshire, UK
I have never understood why many gamblers don't understand this fundamental equation: total winnings are equal to the total stake money minus the casino's expenses and profits. If a casino customer were to be making a living from gambling, it would be at the expense of the vast majority who lose, not of the casino.

Stephen Johnson
Eugene, Oregon, US
Professional gamblers don't make their money by playing against the house. In games like roulette, dice or blackjack, the house always wins, even if it sometimes has to create rules that limit strategies such as card counting.

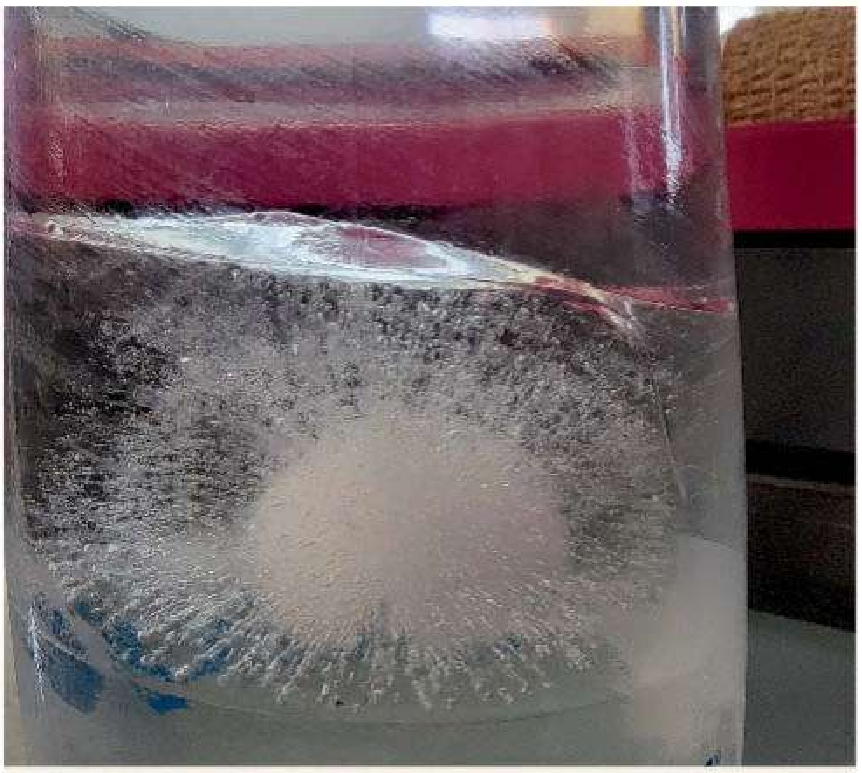
Successful gamblers win by playing against other people, not the house. The classic example is poker, where the winnings come from the other players. The house takes a percentage of each pot for its share of the profits.

Professional gamblers are masters at predicting when their opponents are bluffing and at capitalising on poor strategies used by other players.

@chrisjej
via Twitter
The odds in a game such as blackjack may change as more cards are played, and hence become known. A skilful player can capitalise when the odds change in their favour.

Poker involves a complex set of odds. The better a player understands those odds, the more likely they are to win against someone who doesn't.

@ifonlyella
via Twitter
Professionals gamble against other people in games of skill, not against casinos or against utter luck – and they know when to stop.


JANET HINZE

Why did this water freeze into a pattern resembling a dandelion head?

This week's new questions

Fluffy freeze **Why does my water freeze in this pattern like dandelion fluff (pictured)?** ***Janet Hinze***, *Gering, Nebraska, US*

All aboard **What is the most efficient way to load passengers into an aircraft: randomly; in blocks; or the passengers in window seats first, followed by those in middle seats, then those in aisle seats?** ***Katy Nau***, *Toronto, Canada*

Memory overload

Is it theoretically possible for our memory to become full to the point where it can no longer record information?

Geoffrey Clark
Douglas, Isle of Man, UK
I can say that at 71 years of age my memory is indeed full of all sorts of stuff, but I can't remember what I had for breakfast! I think my brain is indeed full.

David Nye
Eau Claire, Wisconsin, US
No. Memory is encoded in the brain by networks of neurons, whose interconnections – called synapses – have been altered so that they are linked together in a way that represents the memory.

The memory of a red apple is represented by a group of neurons that respond to the colour red, connected to a group that respond to the round shape, and another group that respond to the taste and so on. The activation of the network of neurons encoding a memory causes it to appear in the mind. The same groups of neurons may be reused in many memories, so the two groups representing round and red will resonate when we think of or see either an apple or a red ball.

There are an estimated 86 billion neurons in the human brain – not all of which are used for memories – and 100 to 200 trillion synapses.

That is a lot of storage, but even if you have completely connected up all of the available neurons and filled your brain with memories, you will be able to add new ones by altering existing connections and repurposing your neuron networks, although that might cause you to lose some weaker memories.

Graham Martin
Wellington, New Zealand
A common clinical test is to give people a series of numbers, then ask them to repeat them in reverse order. Most of us can only manage this for a series of four numbers, and a few people can manage five.

Anthony Woodward
Portland, Oregon, US
Sherlock Holmes thought that

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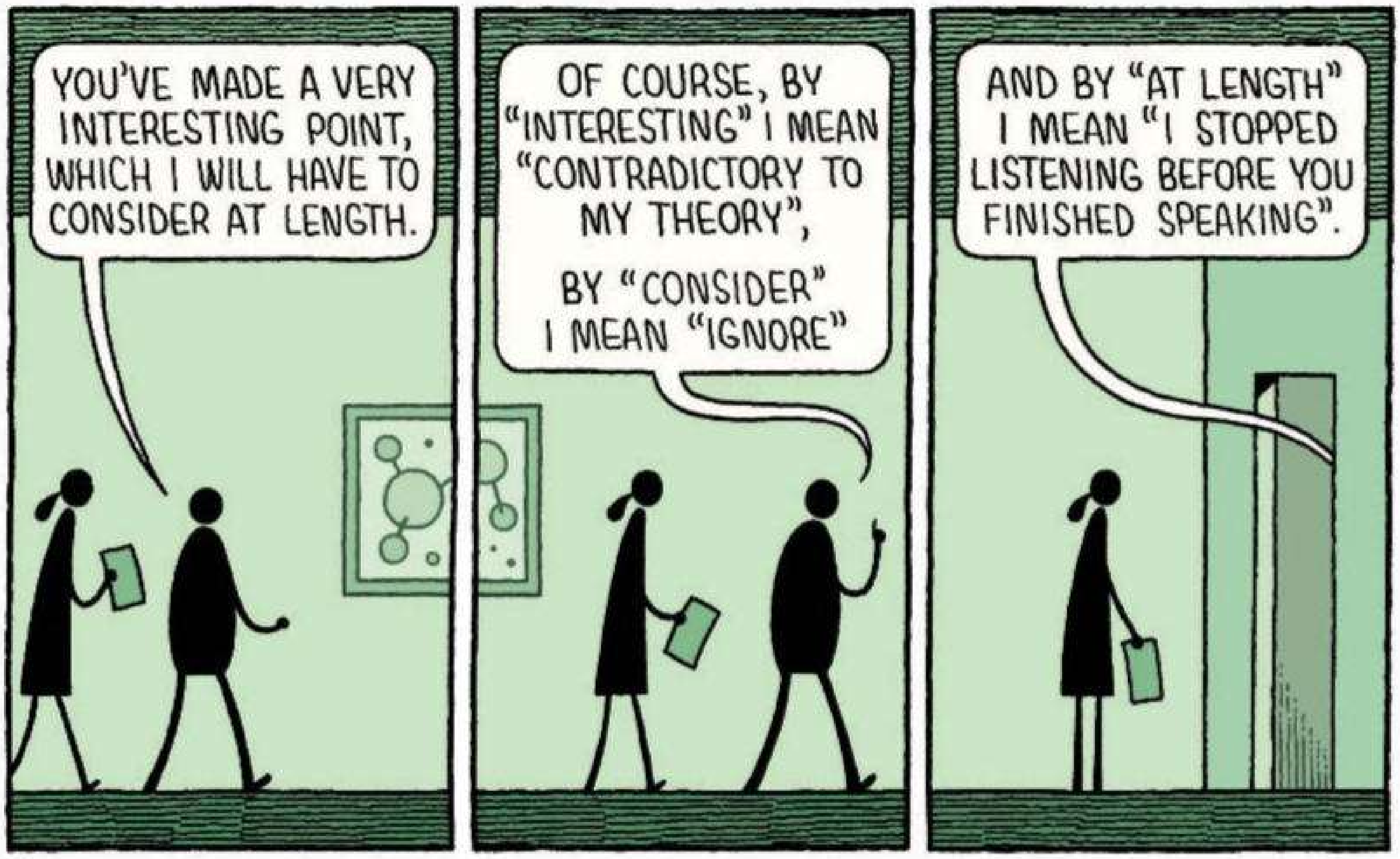
YOU'VE MADE A VERY INTERESTING POINT, WHICH I WILL HAVE TO CONSIDER AT LENGTH.
OF COURSE, BY "INTERESTING" I MEAN "CONTRADICTORY TO MY THEORY", BY "CONSIDER" I MEAN "IGNORE"
AND BY "AT LENGTH" I MEAN "I STOPPED LISTENING BEFORE YOU FINISHED SPEAKING".

his memory had limits. To the astonishment of Dr. Watson at Holmes's ignorance of the Copernican theory, he responded "I consider that a man's brain originally is like a little empty attic", which he didn't wish to fill up with irrelevant data. But the question of whether Holmes was right is bedevilled by our ignorance of how memories are formed.

Dictionaries define memory as the ability to store and retrieve information. This faculty rests in the brain. The information is gathered largely through sensory systems, but we can remember dreams and even remember having memories that seem to be secondary regurgitations of primary memories.

The consolidation of long-term memory involves permanent and repeatedly reinforced changes in the proteins of certain neurons and in the function of their synapses. The astronomical numbers of neurons and synapses that are present in the brain suggest that there will always be room for more memories.

> **"At 71 years of age, my memory is full of all sorts of stuff, but I can't remember what I had for breakfast"**

We can answer the question "How much water can I put in my bathtub?" because we know the total volume of the container and have a unit of volume for water. But we are ignorant of the container of memories and we have no unit of memory. Therefore, we cannot answer the question "How much can I put in my memory?"

Has a professional pianist ever hesitated to add another sonata to their repertoire, or an actor ever refused another play, because they have already filled their memory?

There seems to be no evidence of any limit to human memory for a healthy brain. However, the situation may be different for a brain affected by a condition such as Alzheimer's disease.

Hillary Shaw
Newport, Shropshire, UK

Our memory probably can't become full because our use of symbols and images facilitates what we might call "partial memory hierarchies".

I don't need to remember the location of every town and city in the world, or the translation of every English word into French, I just need to remember where my atlas and French dictionary are. I also need to remember what those 26 squiggly shapes mean when strung in different sequences, but I don't need to know all of the valid sequences.

Going one hierarchical stage up, I just need to remember where my computer is and how to use the internet, or remember where the nearest library is, to have access to an even wider range of "memories" laid down outside my brain. The Dewey Decimal System means I don't even have to remember what books are found where in that library. This hierarchy appears to have no fixed limits to its capacity. ▮

Answers

Quick quiz #180
Answers

1 Rodents, which make up around 40 per cent of mammals
2 Wilhelm Johannsen
3 The termination shock
4 Muons
5 Clouds

Cryptic crossword #97 *Answers*

ACROSS 8 Weevil, **9** Bung, **10** Mosquito, **11** Taffeta, **13** Plant, **15** Smart, **17** Cricket, **20** Bugbears, **21** Wart, **22** Cicada, **23** Mantis

DOWN 1 Beluga, **2/7 Across** Stag beetle, **3** Termite, **4** Twist, **5** Republic, **6** Bitten, **12** Firebrat, **14** Irksome, **16** Moulin, **18** Earwig, **19** Naiad, **21** Wing

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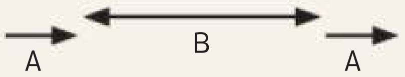
#195 Shuttle space
Solution

Bart should drop the three friends 1 kilometre from the pizzeria. We know Jeff walks a certain distance and is then driven the rest of the way. The three friends are driven and then walk. Since the walking and driving speeds are fixed, to arrive at the same time, Jeff and the three friends must walk the same distance (A). Call the distance between the drop-off point and pick-up point B.



We know that A+B+A = 5km. The distance the car drives between setting off and picking up Jeff is A+2B and this is seven times as far as Jeff walks, so A+2B=7A. Hence 2B=6A, ie B=3A. This means 3A +2A=5km so A=1km. Bart drives 4 kilometres, drops his friends, drives back to pick up Jeff and then drives to the pizzeria.

Sing it loud

'Tis the season, the holiday season, for an onslaught of conversation, karaoke and other activities that swell voices – risking injury to vocal cords. A Finnish research team has explored whether water-infused smoke would be an effective healthcare tool for people who vocalise too dryly. They explain, in the *Journal of Voice*, that "regardless of the reason, vocal fold dehydration impairs the oscillation of the vocal fold tissue".

The team used a waterpipe (the kind of device sometimes known as a hookah or shisha) to apply "a superficial hydration treatment in voice production in healthy young women". The treatment, they report, "seems to be efficient".

Their analysis centred on phonation, which means making the various sounds that, when combined, become human speech. The women, 36 in number, were all "first-year students in the Degree Programme of Logopedics at Tampere University", Finland. Logopedics is the study and treatment of speech problems.

This work explicitly builds on insights gained two decades ago by researchers at the University of Hong Kong. They, too, published in the *Journal of Voice* – a study called "Effect of hydration and vocal rest on the vocal fatigue in amateur karaoke singers".

The team studied "the performance of 20 young amateur singers (10 males and 10 females, aged between 20–25 years)… during continuous karaoke singing". Half of the singers were given water to drink and were permitted short "vocal rests at regular intervals during singing". The other half "sang continuously without taking any water or rest".

The researchers found that while those given water and rests sang for "significantly longer" than their counterparts, "the voice quality, as measured by perceptual and acoustic measures, and vocal function, as measured by phonetogram, did not show any significant changes during singing in the subjects who were given water and rest during the singing".

One implication from that intensive Hong Kong experiment: most karaoke singers manage to keep the quality of their singing fairly constant, no matter what.

Twisteddoodles *for New Scientist*

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Consideration of items sent in the post will be delayed

Kinetic excitement

Does the word "kinetics" intrigue you? The term usually pertains to chemistry or physics. Chemists say kinetics when they discuss the rates at which chemical reactions happen (as in the new study "Kinetics of active oxide species derived from a metallic nickel surface for efficient electrocatalytic water oxidation").

Physicists say kinetics when they analyse the motions of physical objects (as in the study "Spacecraft geometry effects on kinetic impactor missions").

But the word "kinetics" recently popped up in a most unexpected context. A medical team deployed that term in a way that seems novel and puzzling.

"The word 'kinetics' made me think," Kees Moeliker – director of the Natural History Museum Rotterdam, the Netherlands – tells Feedback. He points us to a report, in *The Lancet*, called "Evidence of human-to-dog transmission of monkeypox virus".

The report, from Pitié-Salpêtrière Hospital in Paris, tells of two men who were infected with monkeypox and apparently passed the disease to a companion. First, we are told the context: "The men reported co-sleeping with their dog. They had been careful to prevent their dog from contact with other pets or humans from the onset of their own symptoms (ie, 13 days before the dog started to present cutaneous manifestations)."

Then the word "kinetics" takes centre stage, in this dramatic passage: "To the best of our knowledge, the kinetics of symptom onset in both patients and, subsequently, in their dog suggest human-to-dog transmission of monkeypox virus."

Greenwashing

Sometimes, the same single word, even if it is dry as lint, can suggest insights about technology. Jennifer Davis writes in about a study called "Morphology, compositions, thermal behavior and kinetics of pyrolysis of lint-microfibers generated from clothes dryer".

An international research team (hailing from Lithuania, Russia, Germany and Egypt) explains that its work is "the first research developed to investigate potential applications of dryer lint in the energy recovery field using a pyrolysis process". The team asserts that "dryer lint produced while drying clothes is an urban waste".

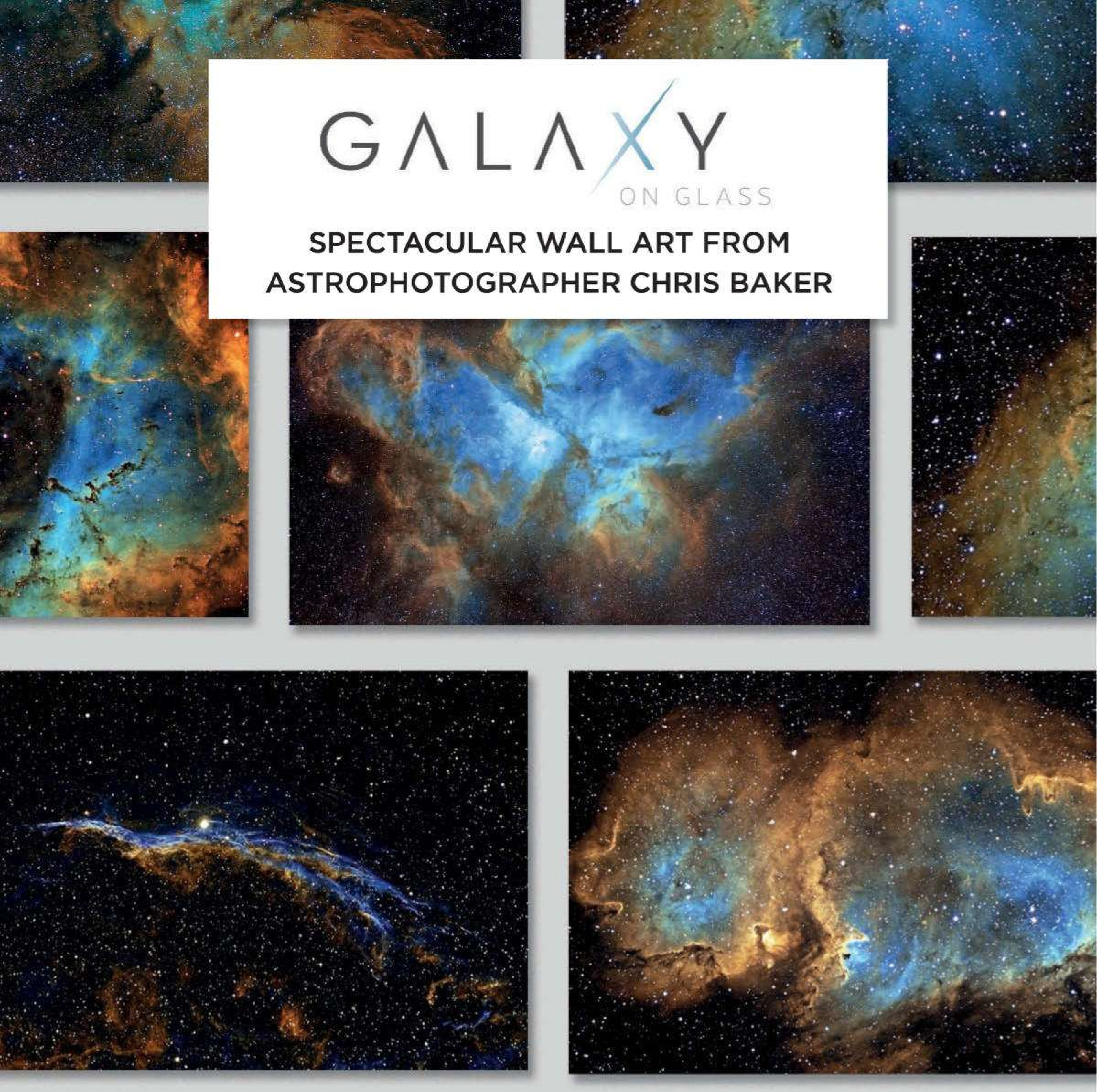
The researchers make and – in an exploratory way – test a simple solution: collect the lint from clothes dryers and burn it to produce a hitherto-neglected "sustainable source of renewable energy".

Perspiration inspiration

Analogous efficiencies are on tap, so to speak, even for the habitually naked. A team based in France and the US explains how this could be in a study called "Wearable biosupercapacitor: Harvesting and storing energy from sweat".

This is an idea that works – if it works – not just when excitement is high and the juices are flowing. The researchers assure us that "the wearable device can store energy and deliver high-power pulses long after the perspiration stopped". (A technical concession for the persnickety reader: Habitually naked except for a wearable biosupercapacitor.) ▮

Marc Abrahams



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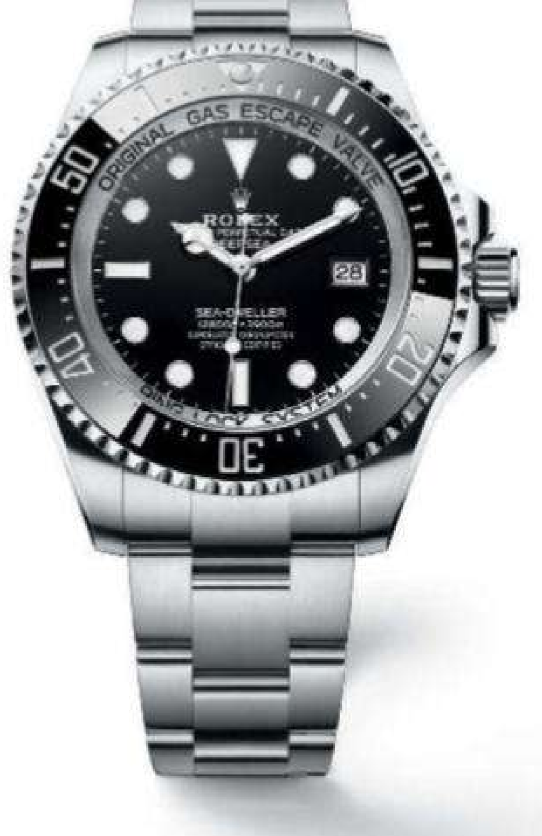

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